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ANALYSIS OF ENERGY PROJECTIONS AND IMPLICATIONS FOR RESOURCE REQUIREMENTS

Prepared for

MISSOURI RIVER BASIN COMMISSION
YELLOWSTONE LEVEL B STUDY

HARZA ENGINEERING COMPANY
Chicago, Illinois
December 1976

SUMMARY LETTER

HARZA ENGINEERING COMPANY CONSULTING ENGINEERS

December 20, 1976

Mr. Robert H. Madsen
Study Manager
Yellowstone Level B Study
Room 332, Transwestern Life Building
404 North 31st Street
Billings, Montana 59102

Dear Mr. Madsen:

We are pleased to submit our report on the energy studies of the Yellowstone River Basin and Adjacent Coal Areas. This report was prepared in accordance with the provisions of our contract dated January 19, 1976, with the Missouri River Basin Commission.

We have prepared a computerized model that estimates energy related demands for water, labor, land, capital, and coal resources in the Yellowstone Study Area under alternative energy development scenarios. The model also measures energy related air emissions including particulates, sulfur oxides (SO_x) and nitrogen oxides (NO_x).

The results of this study should not be viewed as representing goals or recommended plans for energy development. Rather, the study results serve to illustrate the implications of three distinct sets of energy policy and program assumptions. The residents of the study area have the ability, acting through their local, state, and Federal Governments, to strongly influence the amount and form of energy development in their area. The model described in this report provides a tool for evaluating a wide variety of alternatives and determining what course of action will most effectively accomplish specific goals.

150 SOUTH WACKER DRIVE CHICAGO ILLINOIS 60606
TEL (312) 855 7000 CABLE HARZENG CHICAGO TELEX 25 35[illegible]

A basic assumption in the design of the study model is that energy resources will be developed in an economically rational manner, subject to relevant technological, environmental, social, legal, and institutional constraints. In other words, the location, amount, and type of energy development was projected on the basis of relative economic advantage, subject to limitations imposed by such factors as the availability of resources, land use, environment, transportation facilities, engineering feasibility, equipment availability, and public attitudes and preferences regarding development and conservation.

Maximum use was made of information available from previous and ongoing studies in the area. New information was developed only to the extent that data gaps occurred or when existing information lacked rigor or documentation. Consequently, our new data collection efforts focused primarily on developing mining cost estimates for the various conditions encountered in the study area.

Arrangements were made with the Federal Energy Administration to use the Project Independence Evaluation System (PIES) model in the "macro analysis". This macro analysis focuses on national energy demands and supply interaction. The PIES model simulates the national energy economy and identifies the Northern Great Plains (NGP) share of national energy production in the years 1985 and 1990. A procedure was formulated to extrapolate the PIES forecast to the year 2000.

The NGP share of energy production, derived by the PIES model, served as input to a linear programming (LP) model used in the "micro analysis." This micro analysis focuses on regional and state energy demand and supply relationships. The LP model determines the type, location, and resource requirements of mining, transportation, and coal conversion activities within the Yellowstone Study Area. The micro analysis was conducted on the basis of low, most probable, and high regional energy development scenarios as described under the Scope of Services in our contract.

Table 1 summarizes coal production and resource requirements for the Yellowstone Study Area in the years 1985 and 2000 under the low, most probable, and high regional energy development scenarios. The high energy development scenario corresponds to the FEA forecast. The others result from environmental, social and other constraints imposed on the regional development. Coal production is in million tons per year, water requirements are in acre-feet of annual consumptive use, land requirements are for coal conversion and mine sites, labor requirements are on the basis of operating personnel in man-year equivalents, and capital requirements are the cumulative construction costs for new mines and coal conversion facilities. More detailed information about the location, resource requirements and pollutant emissions of the various activities is presented in Chapter III, Micro Analysis, and the Technical Appendices.

A sensitivity analysis was conducted using the LP model to determine the influence on the study results of changes in key parameters or assumptions. This analysis demonstrates how the model can be used to evaluate the consequences of alternate policies and plans as well as changing technologies or economic conditions. For example, water costs have a potentially strong influence on water requirements for cooling of coal conversion facilities. Wet cooling processes, which involve relatively high consumptive uses, are economically preferable to dry cooling processes up to a water cost of about $450 per acre-foot for base load plants, and about $750 for intermediate load plants.

Land use conflicts are likely to influence the pattern of coal mining, but are not expected to influence the total amount of coal production in the area. Coal reserves are adequate to support the production levels indicated by the high scenario to the year 2000 without disturbing existing towns, highways, irrigated lands, monuments, parks, National Forests, wildlife refuges, wild lands, or other units of the wilderness system. However, air and water pollutant emissions could create environmental problems even if individual coal conversion plants meet current standards. Plant sizes,

locations, and concentrations will be influenced by proximity to population centers and air shed considerations.

The remainder of this volume consists of the report and five technical appendices. We are very pleased to have been of service in this challenging assignment.

Sincerely,

T. Esser

T. Esser
Vice President

Encls: As Noted

Table 1

SUMMARY OF COAL PRODUCTION AND RESOURCE REQUIREMENTS
FOR THE YELLOWSTONE STUDY AREA IN THE YEARS 1985 AND 2000

Scenario	Area	Coal (Million Tons/Year) 1985	Coal (Million Tons/Year) 2000	Water[1] (Acre Feet/Year) 1985	Water[1] (Acre Feet/Year) 2000	Labor[2] (Man-year equivalent) 1985	Labor[2] (Man-year equivalent) 2000	Capital[4] (Million Dollars) 1985	Capital[4] (Million Dollars) 2000	Land[5] (Acres) 1985	Land[5] (Acres) 2000
Low Forecast	North Dakota	11.0	11.0	20,592	20,592	379	379	26	26	1,716	1,716
	Montana	25.5	25.5	16,524	16,524	634	634	0	0	1,803	1,803
	Wyoming	74.5	74.5	9,586	9,586	1,540	1,540	295	295	2,654	2,654
	Total Yellowstone	111.0	111.0	46,702	46,702	2,553	2,553	321	321	6,173	6,173
Most Probable	North Dakota	17.25	112.36	35,879	203,87[illegible]	1,357	8,479	1,603	11,158	3,931	16,57[illegible]
	Montana	104.14	268.84	29,969	79,4[illegible]	2,122	7,948	591	5,497	4,543	11,48[illegible]
	Wyoming	41.43	131.92	8,185	44,11[illegible]	823	4,471	197	3,821	1,633	5,927
	Total Yellowstone	162.82	513.10	74,033	327,419	4,302	20,898	2,393	20,478	10,107	33,990
High Forecast	North Dakota	54.1	158.26	115,987	224,7[illegible]	2,868	10,755	3,733	13,362	10,992	18,663
	Montana	136.3	430.1	49,197	218,932	2,665	12,334	616	8,237	5,039	16,855
	Wyoming	103.47	203.47	34,145	92,323	1,971	7,136	515	6,336	3,494	9,146
	Total Yellowstone	293.9	791.8	199,329	556,032	7,503	30,225	4,865	27,936	19,525	44,665

1/ Assumes an adequate water supply can be delivered on a timely basis at a cost of less than $450 per acre-foot.

2/ Annual consumptive use for mining operations, reclamation, coal fired thermal electric plants, coal gasification plants, and coal slurry pipelines.

3/ Operating personnel for mines and coal conversion plants in man-year equivalents per year.

4/ Cumulative construction cost at 1975 price levels of all new mines and coal conversion facilities.

5/ Area in mine and coal conversion sites.

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FOREWORD

The studies presented in this report were performed in accordance with a contract dated January 19, 1976, between the Missouri River Basin Commission and Harza Engineering Company.

Report Format

This volume consists of: (1) a summary letter providing an overview of the study methods and results; (2) a report describing the study purpose, scope of investigations, analytical model, and study results; and (3) five technical appendices documenting the study model and sources of information.

The summary letter contains the essential facts about the study of interest at the executive level. The report and technical appendices provide the Yellowstone Study personnel with the detailed information necessary to perform the other non-energy aspects of the Level B study.

Acknowledgements

Numerous officials of Federal and State Agencies provided guidance and assistance in conducting the studies. We are especially grateful to Mr. Frank G. Zarb, Administrator, Federal Energy Administration, and his staff for their cooperation and guidance in using the Project Independence Evaluation System for the national energy analysis. Messrs. Walter G. Dupree, Jr. and John S. Corsentino, Bureau of Mines, U.S. Department of the Interior, also provided much useful information on national and regional energy outlook.

Messrs. Robert Madsen, Paul Shore, Keith Corrigall, and Donald Ohnstad of the Missouri River Basin Commission played a key role in the intra-regional analysis. Information obtained in their public participation program and from their personal knowledge of the study area was very useful in defining the State and regional energy scenarios. Principal participants of the Harza staff were:

Theodore Esser, Project Director
Jerry W. Knapp, Project Manager

Francois Brucker, Power Systems Economist
Walter Garvey, Water Resources Planner
Roland I. Erickson, Senior Mining Engineer
John Cogan, Geological Engineer
Henry H. Chen, Power Planning Engineer
Raymond K. Duros, Environmental Analyst

Consulting services in conceptualizing the study model, assembling basic data, and preparing the report were provided by Dr. F. Larry Leistritz, Associate Professor, North Dakota State University; Dr. Edward A. Beimborn, Director of the Center for Urban Transportation Studies, University of Wisconsin-Milwaukee; and Dr. Yacov Y. Haimes, Professor of Systems Engineering, Case Western Reserve University. Dr. W. C. Chambers, Manager, Energy Planning Research, Institute of Gas Technology, participated in the coal gasification and liquefaction studies.

Chapter I

STUDY BACKGROUND

Purpose

The national energy situation has a special meaning for residents of the western states. While all Americans are concerned with the economic hardships imposed by scarce supplies and higher costs of energy, energy-rich areas of the West also are being confronted with conflicts in resource use associated with potential large-scale development of their coal and other energy resources. These conflicts are particularly important in the Yellowstone River Basin states of Montana, North Dakota, and Wyoming. These three states contain about 60 percent of the nation's strippable coal reserves and the potential exists for a major expansion of coal mining and coal conversion (e.g., electric generation, gasification) in the region (2, 3 in Bibliography). Because the potential expansion of energy-related activities could require substantial quantities of water and could have massive effects on both the natural and the human environment in these states, the need for careful planning is obvious. However, effective planning requires analytical models capable of forecasting the level, type, and location of future energy development and the resource requirements under alternative energy policies and programs.

The primary purpose of this study was to develop a planning tool for use by others who are conducting a "Level B" (reconnaissance level) planning study of the water and related resources in the Yellowstone River Basin and Adjacent Coal Areas. Three basic energy scenarios for the years 1985 and 2000 were defined and the corresponding requirements for water, capital, labor, land, and mineral resources were determined. These scenarios are presented for use by planning teams in the plan formulation process, where demands for resources in alternative uses, such as for agriculture, will be considered.

The results of this study should not be viewed as representing goals or recommended plans for energy development. Rather, the study results serve to illustrate the implications of three distinct sets of energy policy and program assumptions. The residents of the study area have the ability, acting through their local, State, and Federal

Governments, to strongly influence the amount and form of energy development in their area. The model described in this report provides them with a tool for efficiently evaluating a wide variety of alternatives and determining what course of action will most effectively accomplish their goals.

Scope of Investigations

The Contract specified the following services:

1) Forecast for the year 1985 and year 2000 the demand and supply of energy on a national level and within the Yellowstone Study Area under the following scenarios:

    A) A low rate of regional energy development including only production to meet local needs and to cover exports that are already guaranteed or highly probable.

    B) A most probable rate of development consistent with national energy consumption and production forecasts.

    C) A high rate of development based on the maximum contribution the study area energy minerals might reasonably be expected to make in alleviating shortages in domestic nuclear generation and eliminating reliance on imported oil and gas.

2) Determine the magnitude of uses of various energy fuels for those portions of the States of Montana, North Dakota and Wyoming in the Yellowstone Study Area, and estimate the quantities that would be exported from each state area to meet national demands by 1985 and 2000, under the scenarios cited above.

3) Determine the corresponding energy transportation systems required within and outside the Yellowstone Study Area for the years 1985 and 2000. Determine the corresponding coal gasification and liquefaction plants, thermal-electric plants, and coal mines which would be developed by 1985 and 2000.

4) Estimate the capital, labor, water, land, and mineral resources which would be required for these energy developments in the Yellowstone Study Area.

5) Estimate the air and water pollutant emissions accompanying these energy developments in the Yellowstone Study Area.

Review of Literature

An exhaustive literature review was conducted at the outset of the study. Nearly two hundred relevant references were assembled for review. They were surfaced by library searches and interviews with the MRBC staff, Federal and State Agency officials, University faculty, industry representatives, and others knowledgeable about the national, state, regional, and local energy situation. Most of the basic data for the study were obtained from these sources. Primary data collection occurred only to fill information voids or when data from other sources required revision or further documentation. A list of primary sources is presented in the Bibliography.

Conceptual Framework

The study involves two major components: (1) a "macro" level analysis which considers national energy supply and demand interaction and identifies the Northern Great Plains (NGP) share of national energy production, and (2) a "micro" level analysis which focuses on the energy development activity of the Yellowstone Study Area. These components are discussed in Chapters II and III, respectively, of this report.

The general approach used in these energy studies differs significantly from other recent studies of the Northern Great Plains area. Previous efforts to forecast energy developments in the Study Area have been based primarily on trend extrapolations. As a result, studies published as recently as April 1975 were based on projected prices for oil of about \$3 per barrel at the well head (1). Current expectations are for prices to continue at a level of about \$13 per barrel c.i.f. United States, in 1975 dollars (2, p. 15). The energy crisis precipitated by the oil embargo has caused major discontinuities in historical trends for energy prices and other variables.

A basic assumption in the study approach is that energy resources will be developed in an economically rational manner subject to relevant technological, environmental, social, legal, and institutional constraints. In other words, the location, amount, and type of energy development are projected on the basis of relative economic advantage within the national energy system, subject to limitations imposed by such factors as the availability of resources (e.g. capital, water, labor, minerals); ownership (e.g. private, Federal, State, Indian Reservations); land use (e.g. urban, irrigation, parkland); environment (e.g. air and water quality standards); transportation facilities; equipment availability; and public attitudes and preferences regarding development and conservation.

The study models are documented in a manner to facilitate periodic updating as additional data become available or changes occur in such factors as foreign relations, technology, public attitudes, or policy.

Chapter II

MACRO ANALYSIS

The purpose of the "macro" analysis is to identify the Northern Great Plains (NGP) share of national energy production in the Years 1985 and 2000 on the basis of comparative economic advantage with other supply regions. The information obtained in the macro analysis provides the basis for estimating the energy related demands for capital, labor, water, land, and mineral resources in the Yellowstone Study Area under alternative State and regional energy development scenarios. The method of deriving these resource demands, as well as air and water pollutant emissions, are referred to as the "micro analysis" and are discussed in Chapter III.

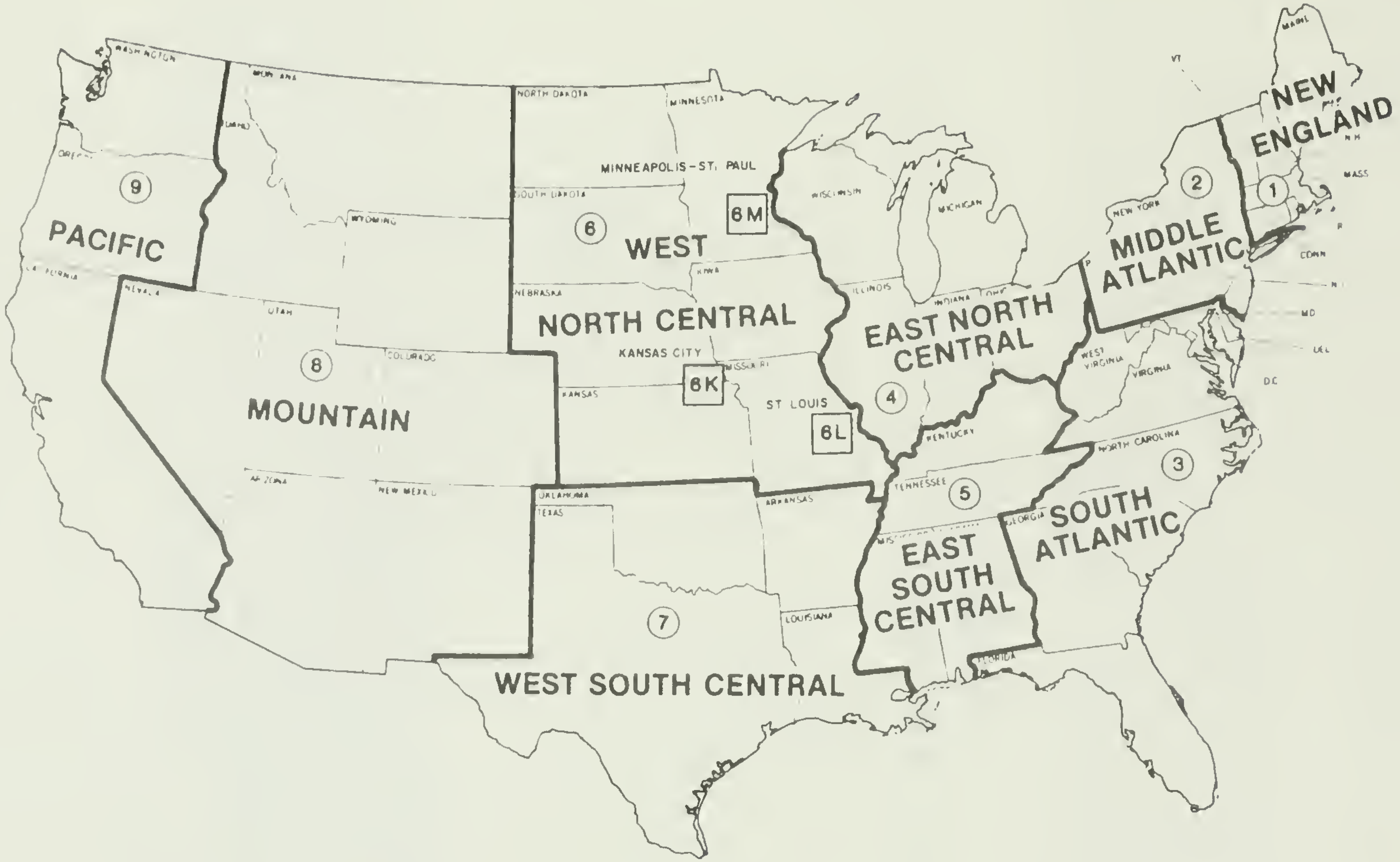
Macro Model

The Project Independence Evaluation System (PIES) developed by the Federal Energy Administration (FEA) has been selected as the basic analytical model for the macro analysis. A description of the PIES model is presented in Appendix A-IV of the 1974 Project Independence Report (3, pp. 195-282). Forecasts based on more recent data and some refinements in the model were published in the 1976 National Energy Outlook (2). Since detailed documentation of the PIES model is available from these sources, only a summary is presented in this report.

The PIES model simulates the national energy system, and produces in a single run: (1) a demand forecast by region, fuel, and price; (2) estimates of the quantities of energy distributed through the entire transportation network that connects the supply and demand regions; and (3) estimates of the capacity and type of conversion facilities needed in each region. The national energy economy is simulated by comparing supply and demand functions of alternative energy forms in a competitive environment to determine equilibrium prices and quantities.

The PIES energy demand analysis is made on the basis of a set of econometrically based sectoral models which project regional final demands for various refined petroleum products, natural gas, electricity, and coal on the basis of census regions. A map of the census or demand regions is presented in Exhibit 1.

EXHIBIT 1



IARZA ENGINEERING COMPANY · DECEMBER 1976

ENERGY DEMAND REGIONS
YELLOWSTONE ENERGY STUDY

Energy supply responses are estimated separately for oil, natural gas, and coal by producing region. The supply regions for coal are presented in Exhibit 2. An overview of the procedures for estimating the raw material supply curves for coal, oil, and natural gas is presented in Appendix D to the 1976 National Energy Outlook (2).

Coal appears to be the only energy fuel produced in the Yellowstone Study Area with associated water requirements sufficient to warrant specific consideration in Level B water resources planning. Consequently, this study focuses primarily on the resource demands and pollutant emissions associated with coal development. A detailed analysis was made of uranium reserves in the area. The results of this analysis are summarized in Appendix A - Mining Analysis.

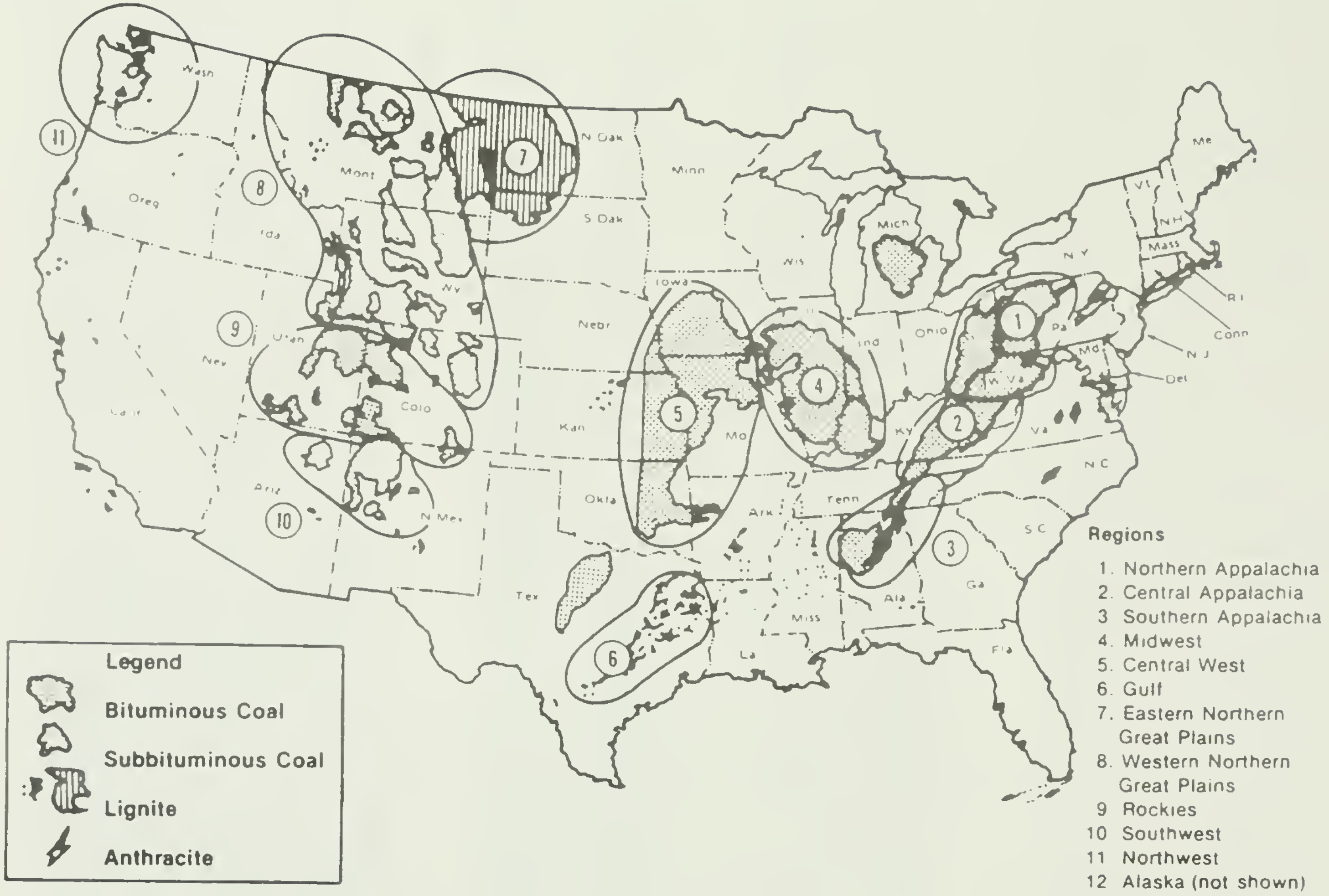
National Energy Scenarios

The national energy scenarios analyzed by the PIES model include:

1) Reference Case
2) Conservation Case
3) Accelerated Case
4) Regulatory Case
5) Electrification Case
6) Regional Limitation Case
7) Supply Pessimism Case

Each of these scenarios is briefly described below. A detailed description of these scenarios is presented in Appendix E to the 1976 National Energy Outlook (2). These scenarios were developed to evaluate the impacts of accelerated development, conservation, government price controls, regional growth restrictions, different expectations about geologic and resource potentials, and the effects of a greater use of electricity. The scenarios do not represent FEA or Administration policy recommendations.

EXHIBIT 2



COAL SUPPLY REGIONS

YELLOWSTONE ENERGY STUDY

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Reference Case

This scenario consists of the "business as usual" (BAU) demand and supply cases. The BAU demand includes the conservation effect of higher energy prices and the impact of the conservation ethic as it is reflected in recent trends, but does not assume the passage of any of the energy conservation actions currently under consideration by the Congress and the Administration, or any changes in State legislation. The characteristics of the BAU supply case are rather complex. The interested reader is referred to Appendix E of the *1976 National Energy Outlook* for a detailed definition of the BAU supply case.

Conservation Case

This scenario reflects a full set of conservation actions on the demand side, including auto efficiency standards, car pooling, thermal efficiency standards, appliance efficiency improvements, accelerated industrial energy conservation, improved airline load factors, electric utility load management, and elimination of gas pilot lights. On the supply side, a BAU case is assumed.

Accelerated Case

On the demand side, this scenario reflects the energy conservation actions described in the Conservation Case.

On the supply side, it is designed to illustrate the effects of an aggressive but achieveable effort to increase domestic energy resource development.

Regulatory Case

This scenario is designed to illustrate principally the domestic supply, demand and import impacts of price regulation and controls. The scenario's supply case assumes that price controls and regulations are in effect for all domestic oil and gas. Two sets of assumptions about price regulation have been developed. In the higher case, domestic oil and gas are regulated at approximately $9/barrel and $1.20/Mcf; wellhead prices, 1975 dollars. In the lower case, the regulated oil and gas prices are approximately $7.50/barrel and $1.00/Mcf. Imports of oil and gas are unconstrained, at world prices. Other assumptions concerning supply are identical with the BAU supply case. The demand case assumed is BAU.

Electrification Case

This scenario is designed to show the impact upon the growth of electricity of a strategy to promote increased electrification of energy end-use. On the supply side, an accelerated coal-nuclear case is used; the demand case embodies increased electrification in the household/commercial and industrial sectors.

Regional Limitation Case

On the demand side, this scenario assumes the business-as-usual case. On the supply side, the scenario assumes that energy development is restricted through a moratorium imposed on nuclear power plant construction, beyond projects currently granted construction permits, decelerated leasing of the Outer Continental Shelf (OCS) through 1980, restrictions on mining and burning of coal including heavier reclamation costs and severance taxes, and mandatory use of scrubbers on all new power plants in conjunction with low-sulfur coal.

Supply Pessimism Case

This scenario is designed to show the adverse impact upon supply of the combined effect of price regulation, regional supply limitation, and geological pessimism with respect to oil and gas finding rates. The major supply assumptions are the conventions for the Regional Limitation Case, combined with oil and gas price regulation at approximately $9/barrel and $1.20/Mcf and with less favorable geological experience, less rapid leasing of Outer Continental Shelf acreage, and diminished ability of the Alaskan North Slope to sustain high rates of oil production in the 1980's.

General Conventions

World Oil Prices

World oil prices have a major influence on the domestic energy situation. It is expected that the oil cartel will be able to maintain prices at near current levels over the study period. However, recognizing the uncertainties surrounding the world oil price situation, FEA has made PIES model runs using various prices ranging from $8 to $16 per barrel delivered to the United States. These prices are expressed in constant dollars, denominated as of July 1975. The

influence of variations in oil import prices on coal production is summarized in the "Results of the Macro Analysis" on page II-9.

Economic Assumptions

Data Resources, Inc.'s "Control Long 5/75 Macroeconomic Forecast" is used for all FEA scenarios. Some of the major assumptions are summarized below. The forecast is described in detail in Appendix B to the *1976 National Energy Outlook* (2).

1) Potential Gross National Product (GNP) is forecast to grow at a rate of 3.3 percent over the 1975 to 1990 period.

2) The population forecast is based on the Census Bureau's Series II Population Projections, which assumes a fertility rate of 2.1 births per woman. This assumption is consistent with recent surveys of expected family size and implies zero population growth in the long term.

3) It is assumed that fiscal policies will be conducted according to stable framework principles. Federal expenditures and tax policies are assumed to be expansionary through the 1970's. The 1980's are pictured as a decade of balanced growth with Federal government purchases of goods and services rising smoothly at a real rate of 2.0 percent and transfer payments to persons increasing at a real rate of 3.4 percent per year.

4) Unemployment is forecast to decline to a long-term equilibrium level of 5 percent by 1981.

5) Gradual economic recovery will bring the inflation rate down to near 4 percent for most of the 1980's.

Extrapolation to the Year 2000

The PIES forecasts extend only to the year 1990. To fulfill the needs of the Yellowstone Level B Study, it was necessary to develop a procedure for extrapolating the PIES forecasts to the year 2000. This involved a search of the literature and an analysis of forecasts made by other,

longer-range models (15, 16, 17, 18, 19, 20 in Bibliography).

The extrapolation approach adopted involved separate projections for three types of coal use:

1) Electric generation (utility)

2) Industrial purposes

3) Synthetic gas production

Primary attention was devoted to the electric generation sector in extending the forecast since it accounts for the largest share of coal use. The following procedure was used to project the study area share of coal use for electric generation:

1) Estimate electric demand by utility region.

2) Estimate the share of this demand to be provided by coal-fired plants.

3) Estimate the share of this coal-fired capacity that will be fueled by coal from PIES Supply Regions No. 7 and 8.

4) Determine the Yellowstone Study Area share of the coal-fired capacity using the micro model described in Chapter III.

Information from the Oak Ridge National Laboratory's _Projections of Electricity Demand_ (19) was used as a basis for extrapolating electricity demand. The rate of growth for the period 1990 to 2000 from the Oak Ridge model was applied to the PIES coal use levels for 1990 to estimate electric demand by utility region for the year 2000. The share of this total electric demand to be provided by coal from PIES Supply Regions No. 7 and 8 was projected by assuming that the 1990 share will prevail in the year 2000.

Industrial use of coal in the year 2000 was derived by using the PIES 1985 and 1990 projections to compute the trend in coal's share of this market.

The year 2000 forecast of coal use for synthetic gas production was made by Harza with participation by the Institute of Gas Technology. The study approach is presented in Appendix C.

The extrapolation procedures used to extend the PIES forecasts are considered to yield a conservative estimate of NGP coal demands for the year 2000. This conservatism may result in a relatively minor understatement of the resource development requirements for the high regional energy development forecast. The effect under the most probable and low regional energy development forecasts would be negligible. As indicated in Chapter III, NGP coal production under these later scenarios is constrained primarily by supply considerations such as transportation capacities, environmental standards, and social preferences.

Results of Macro Analysis

An analysis of the various FEA national energy scenarios led to the conclusion that the Reference case with $13 cil import cost was a suitable baseline national senario for use in the Yellowstone studies. The estimate of NGP coal consumption provided by this scenario is used as the high regional energy development forecast. This is because the coal supply curves included in this run of the PIES model impose only minimal constraints on coal development (22, p. 16). The assumptions and procedures used in deriving the coal supply curves for the PIES model are documented in the FEA report entitled PIES Coal Supply Curve Methodology (22). The indications from this report that the supply curves correspond to a high regional energy development forecast, were confirmed by runs of the linear programming model developed by Harza (see Chapter III).

As previously indicated, the BAU demand case used in the Reference Scenario includes the conservation effect of higher energy prices, but does not assume passage of any of the energy conservation measures currently under consideration by the Congress and the Administration, or any changes in State legislation.

The effects of imposing economic, social, environmental, and institutional constraints corresponding to the most probable and low regional forecasts are presented in Chapter III. It is important to note that the imposition of State or regional constraints on energy development would likely result in (1) an increase in the national energy cost, or (2) a decrease in national energy consumption, or (3) the imposition of countervailing constraints in other producing regions, or (4) some combination of these and other effects.

The national energy impacts of regional constraints on coal development could be analyzed by additional runs of the PIES model. Such an analysis should be undertaken if national as well as state and regional impacts are to be included in the Yellowstone Level B Study.

The results of the macro analysis, as presented in this section, are summarized primarily from the 1976 National Energy Outlook report (2).

National Energy Demand

A continuation of current energy prices will significantly reduce the growth rate in energy demands. At current price levels, national energy demand is forecast to increase from 72.9 quadrillion BTU (quads) in 1974 to 98.9 quads in 1985. This represents a growth rate of 2.8 percent, compared with the recent historical rate of 3.6 percent.

An active conservation program such as described in the PIES Conservation Case could further reduce energy demand by the equivalent of 3 million barrels of oil per day, reducing the annual energy growth rate to 2.2 percent through 1985. While conservation can reduce energy demand, it does not appear feasible to obviate the need for expanding national supplies.

The largest growth in consumption will occur in electricity use (electric sector), which will increase at an annual rate of about 5.4 percent per year. This is nearly twice the growth rate of overall energy demand, but represents a substantial reduction from the 7 percent per year increase experienced over the past 20 years.

The rate of growth in national energy demand is highly sensitive to energy prices. For example, if world oil prices decline to $8 per barrel, energy demand will grow at an annual rate of about 3.2 percent.

National energy consumption will gradually shift from oil and gas to coal and nuclear power over the study period. These shifts will occur due to dwindling oil and gas reserves, and result in a relative economic advantage. for coal. For example, in the electric sector coal is readily substitutable for petroleum in new thermal electric facilities. The PIES model indicates that the electricity from a new baseload,

coal-fired plant is cheaper than the electricity from an oil-fired plant if oil is above $9 per barrel. Further, when oil is above $10.50 per barrel, it is economic to build a new coal fired plant for baseload and shift an existing oil fired plant to intermediate load. However, even at $13 per barrel import prices, a considerable amount of petroleum will continue to be used for intermediate and peak loads in existing oil-fired plants. Under these conditions, these facilities are still economically viable because they are run relatively infrequently and the costs of construction are sunk costs (2, p. 17).

National and Regional Energy Supply

The 1976 National Energy Outlook report states: "The United States has vast reserves of coal amounting to three times the energy contained in Middle East's oil reserves, and currently accounting for more than 90 percent of U.S. proved energy reserves. Yet over the last 75 years, the United States has switched from using coal for over 90 percent of its energy needs to depending on oil and gas for 75 percent of its energy. Thus, the Nation depends upon its least abundant energy resources to provide most of its energy needs" (2, p. xxii).

Oil Production

Domestic oil production has been declining since 1970, but is expected to stabilize and increase as a result of production from Alaska, enhanced recovery projects, and OCS leasing. Production is expected to increase from a low of 8.2 million barrels per day (MMB/D) in December 1975 to 13.9 MMB/D by 1985, including co-products. But production will begin to decline again by 1990. This oil supply forecast by FEA is based on a "Business-as-usual Outlook" which the U.S. Geological Survey (USGS) regards as having a 50-50 chance of proving valid in actual practice over time (2, p. 61). However, there is considerable uncertainty about future domestic oil supply due primarily to a lack of information on geological potential, technology related to tertiary recovery, and energy policy (e.g. leasing arrangements).

Natural Gas Production

Natural gas currently supplies about 30 percent of the total national energy needs. About 93 percent of domestic

production is derived from the States of Texas, Louisiana, New Mexico, Oklahoma, Kansas, and California. Natural gas marketed production peaked at 22.6 trillion cubic feet (TCF) in 1973 and declined to 21.6 TCF in 1974. Production is expected to continue declining in the next few years, but will increase again to 22.3 TCF by 1985 if gas prices are deregulated. If regulation of the interstate market continues, production is expected to decline to 17.9 TCF in 1985. Low regulated prices encourage consumption and therefore result in more rapid depletion of known reserves. Furthermore, the low prices tend to discourage exploration for new gas reserves.

Nuclear Power Production

Nuclear power production forecasts have been recently revised substantially downward. About 105,000 megawatts of planned nuclear capacity were deferred or cancelled between September 1974 and February 1976 (2, p. 36). These cutbacks are attributed to lower projections of electricity demand, financial problems experienced by utilities, uncertainty about government policy, and complex continued siting and licensing problems. However, even with these reductions, nuclear power is forecast to increase to about 26 percent of electric generation by 1985 compared with 9 percent in 1975.

The FEA forecasts indicate that a nationwide moratorium on new nuclear power could increase national coal requirements by more than 200 million tons, in addition to the 400 million tons increase already projected in the Reference case for 1985. An alternative to increased coal production would be to increase oil imports by about 2 million barrels per day. The implications of a moratorium on nuclear power would be even more severe by the years 1990 or 2000. For example, coal production in 1990 would increase to more than three times the present national production if nuclear power is subjected to a prolonged moratorium or other long-range restraint.

Coal Production

The FEA forecast of national coal production is 1,040 million tons in 1985 ($13 oil imports). At that production level, the U.S. has enough coal reserves to last at least 200 years.

Over half the U.S. coal production occurs in two regions - the Western Northern Great Plains and Central Appalachia. One of the primary reasons for the concentration of production in these regions is that they both have substantial reserves of low sulfur coal. The Northern Great Plains area (PIES Supply Regions Nos. 7 and 8) is forecast to produce about 305 million tons of coal in 1985 which amounts to about 30 percent of the projected national production for that year.

A summary of the PIES coal production forecasts by region under various price levels for imported oil is presented in Table II-1. Variations in oil import prices would have a significant effect on this forecast. For example, if oil import prices dropped from $13 to $8 per barrel, coal production in the Northern Great Plains area would decline nearly 24 percent to 233 million tons under the Reference Case for 1985. On the other hand, if oil import prices increased to $16 per barrel, NGP coal production would increase 7 percent to 325 million tons. These differences are related primarily to the marginal at which coal substitutes for oil in the electric utility sector.

Coal production for the United States and the Northern Great Plains under the various national energy scenarios is summarized in Table II-2. The lowest production in the Northern Great Plains area of 249 million tons occurs under the Regional Limitation Case. The highest production in the Northern Great Plains of 438 million tons occurs under the Electrification Case.

Table II-1

COAL PRODUCTION BY REGION[1]
REFERENCE CASE FOR 1985 (Million Tons)

Region	Oil Import Price $8	 $13	 $16
Western Northern Great Plains	219	274	293
Eastern Northern Great Plains	14	31	32
Subtotal Northern Great Plains	(233)	(305)[3]	(325)
Northern Appalachia	159	183	183
Central Appalachia	285	297	298
Southern Appalachia	22	25	25
Midwest	130	156	175
Central West	9	9	9
Gulf	20	21	21
Rockies	19	19	19
Southwest	16	21	24
Northwest	1	4	6
Alaska	[2]	[2]	[2]
United States	894	1,040	1,085

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[1] Source - Project Independence Evaluation System (PIES)

[2] Less than 500,000 tons

[3] This includes 208.6 million tons for utility use and 96.4 million tons for other uses, based on "average" Btu values for NGP coal; when converted to specific Btu values for each NGP mining area, this number becomes 346.4 million tons.

Table II-2

COAL PRODUCTION IN 1974 AND UNDER VARIOUS NATIONAL ENERGY SCENARIOS IN 1985, $13 OIL IMPORTS [1]

(Million Tons)

Scenario		Coal Production U.S.	Coal Production Northern Great Plains [2]
1974	Historical	603.4	42.1
1985	Forecasted		
	Reference Case	1,039.4	305.1[3]
	Conservation Case	971.6	261.8
	Accelerated Case	1,014.3	274.8
	Regulatory Case	995.9	286.1
	Electrication Case	1,258.2	437.7
	Regional Limitation Case	958.0	248.9

---

[1] Source - Project Independence Evaluation System (PIES)

[2] PIES Coal Supply Regions 7 and 8 (See Exhibit 2).

[3] See Note 3 on Page II-14

The consumption of Northern Great Plains coal by demand region and type of coal for industrial and utility use in the years 1985, 1990, and 2000 is summarized in Table II-3. These quantities of coal, along with the amounts converted to high Btu gas, represent the points of interface between the macro and micro models. They are used as the coal demands for the high forecast in the linear programming model used for the micro analysis.

Other Energy Sources

National energy production from emerging technologies, such as solar, geothermal and synthetic fuels is not expected to be significant by 1985 (2, p. 38). Solar electricity capacity in the U.S. will amount to about 500 megawatts in 1985 and geothermal power will amount to about 1650 megawatts. FEA studies indicate that little if any production of synthetic fuels can be expected in the next ten years unless financial incentives are provided.

Energy production from these sources is expected to increase dramatically after 1990 as domestic oil and natural gas supplies dwindle. The technology for producing energy from these sources exists, but must be proven economically viable on a commercial scale. In addition there are numerous environmental and socioeconomic problems which must be resolved before the potential of these energy sources can be developed. The potential for synthetic gas production in the Yellowstone Study area is analyzed in Appendix C.

Table II-3

CONSUMPTION OF NORTHERN GREAT PLAINS COAL BY REGION AND TYPE REFERENCE CASE FOR 1985, 1990, AND 2000[1]

		Consumption of NGP Coal (Million Tons Per Year)					
		Industrial Use			Utility Use		
Demand Region	Type of Coal[2]	1985	1990	2000	1985	1990	2000
East North Central	Low-Btu, Low Sulfur	47.6	74.9	102	74.6	145.5	186
East South Central	Low-Btu, Low Sulfur	24.4	13.4	18	15.2	35.8	45
West North Central	Low-Btu, Low Sulfur	12.3	15.1	21	27.8	43.2	57
	Very Low-Btu, Low Sulfur	-	-	-	25.2	38.9	53
	Very Low-Btu, High Sulfur	-	-	-	6.1	6.1	8
West South Central	Low-Btu, Low Sulfur	0.3	0.4	1	13.5	60.0	77
Mountain	Low-Btu, Low Sulfur	4.9	5.8	8	30.5	33.4	43
	Low-Btu, High Sulfur	-	-	-	15.7	29.5	37
Total		89.5	109.6	150	208.6	392.4	506
Trillions of Btu		1700	2082	2850	3807	7231	9309

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[1] Source - Project Independence Evaluation System (PIES) model for years 1985 and 1990 extrapolated to year 2000. Does not include coal converted to high Btu gas. Represents a high regional forecast.

[2] In the PIES model, coal is classified in five categories with respect to its BTU contents, as follows:

High	24 Million Btu/ton
Medium	22 Million Btu/ton
Low	19 Million Btu/ton
Very Low	14 Million Btu/ton

Chapter III

MICRO ANALYSIS

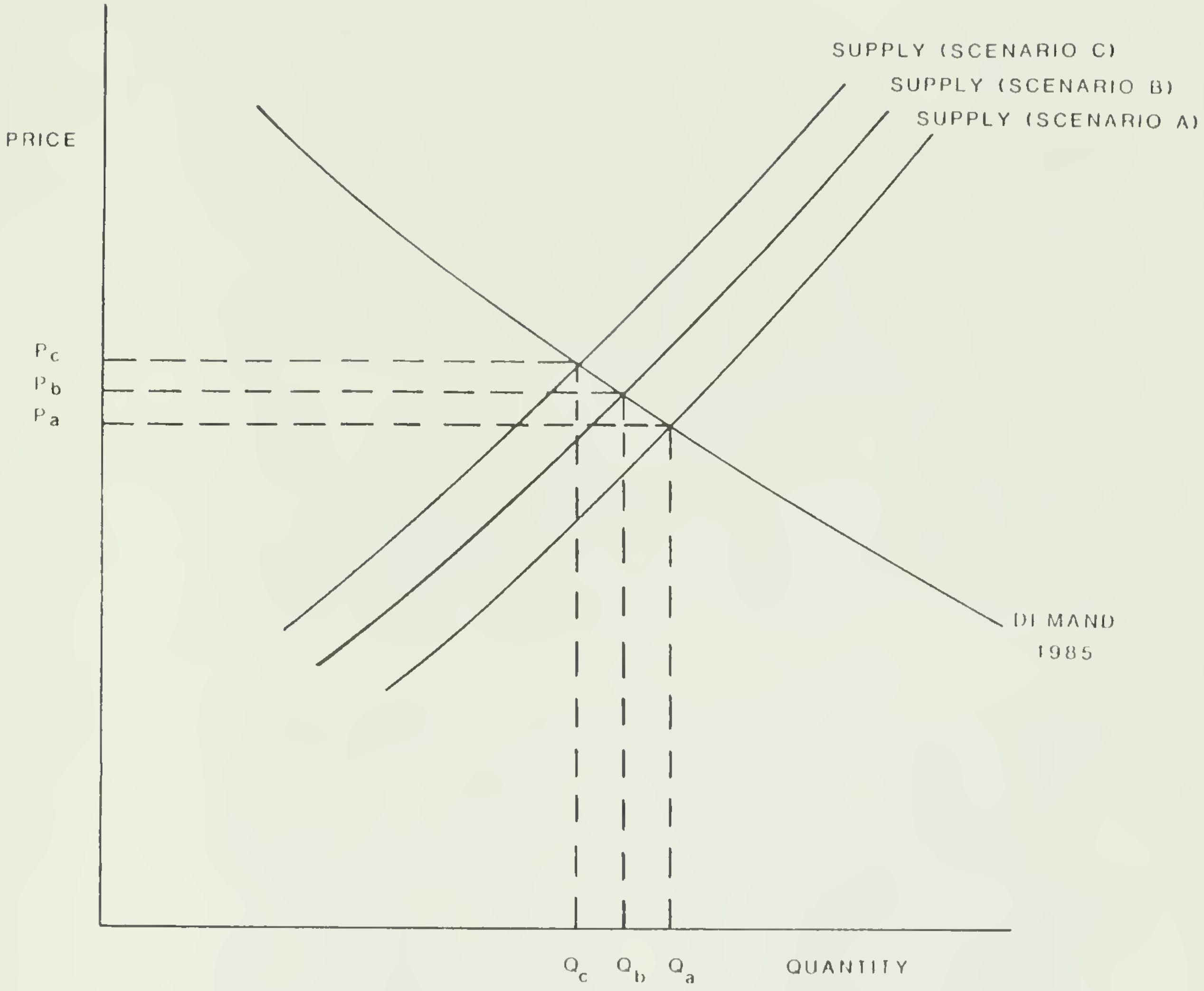
The purpose of the "micro" analysis is to disaggregate the energy production forecasts made in the "macro" analysis and predict supply responses within the Yellowstone Study Area under alternative regional energy development scenarios. A linear programming (LP) model was developed to determine the type, location, and resource requirements of mining, transportation, and coal conversion activities that can be expected to occur in the study area for a given scenario and time period. The resource requirements considered include water, labor, capital, land, and minerals. Estimates also were made of associated air and water pollutants.

The micro analysis was conducted on the basis of the low, most probable, and high energy development scenarios described above in the section entitled "Scope of Investigations". These scenarios represent different levels of resource development that might occur in the Yellowstone Study Area as a result of exogenous factors. For the initial runs of the model, the assumption was made that presently existing taxation and environmental policies will remain relatively unchanged into the future. However, the residents of the Yellowstone Study Area have the ability, acting through their local, State, and Federal Governments, to strongly influence the amount of energy development in their area. For example, high severance taxes on coal can shift production to other supply regions. The model used in the micro analysis has been designed to enable the testing of different energy policies to determine their effects on energy development patterns in the study area. The low, most probable, and high energy development scenarios correspond to different regional supply response curves. A hypothetical illustration of the influence of different regional supply response curves for coal is presented in Exhibit 3. The regional share of national coal production in this example would vary from Q_a to Q_c depending upon the regional energy policies and programs adopted.

Micro Model

The linear programming model uses a cost minimization algorithm to meet as much of the demand for utility and

EXHIBIT 3



HYPOTHETICAL COAL SUPPLY & DEMAND RELATIONSHIPS FOR ALTERNATIVE DEVELOPMENT SCENARIOS IN THE NORTHERN GREAT PLAINS AREA

industrial coal, indicated in the macro analysis (Table II-3), as is feasible subject to a set of constraints. These constraints include those imposed by laws and regulations that were in force on January 1, 1976, and by physical capacity limits on mining, conversion, transportation, and resources.

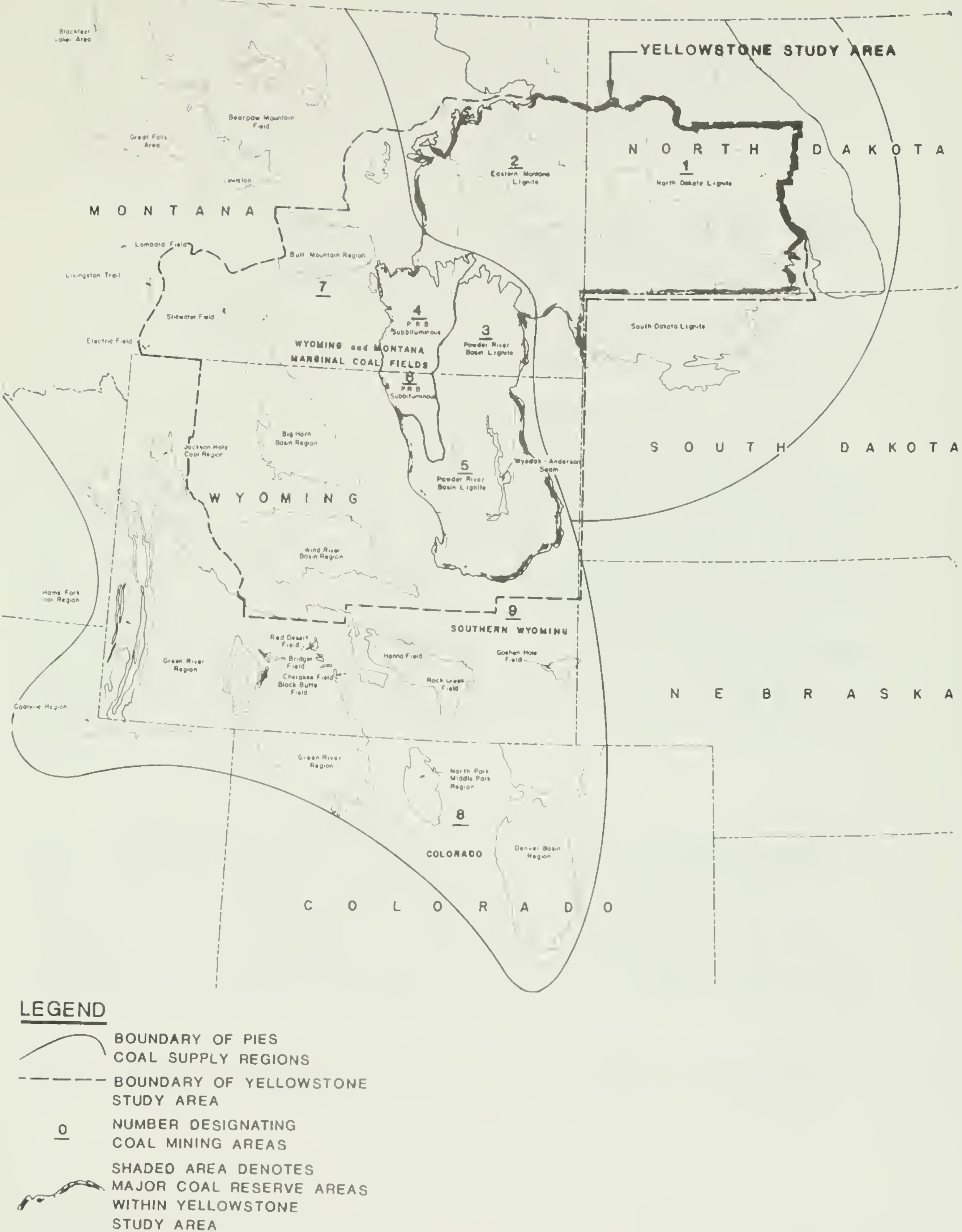
Four steps are considered in the process of meeting the demand for coal. These include:

1) Mining. For purposes of the micro analysis, the PIES Coal Supply Regions No. 7 and 8 were divided into fourteen homogeneous mining areas. The delineation of mining areas was made on the basis of state boundaries, physiographic basin, and rank of coal. A map showing the boundaries of these mining areas in presented as Exhibit 4. Appendix A, Mining Analysis, contains the detailed information from which the input to the model was derived. The analysis showed that eight of the fourteen mining areas have sufficient potential for development to warrant inclusion in the model. Six of these eight mining areas are within the Yellowstone Study Area. Two are outside the study area, but within PIES Coal Supply Regions No. 7 and 8. Mining costs and capacities were included separately for existing and new mines with low, medium and high overburden ratios in each mining area. The annual production of new mines was limited to ensure a mine life of at least thirty years, based on demonstrated strippable reserves.

2) Transportation to Processor. Provisions are made in the model to transport utility coal to a processing site by unit train, slurry pipeline, or a unit train - waterway combination. Industrial coal is transported by conventional train. The processing sites can be located at the demand points, at potential sites in the study area, or at mine mouth sites. If the processing of coal is to occur at mine mouth, transportation costs for coal movement are zero. Both costs of transport and capacity constraints were determined for all mining area and demand area combinations and for each of the alternative transportation modes.

3) Processing. At the processing site, the coal can be converted to electricity or synthetic gas, or

EXHIBIT 4



STUDY AREA MAP
YELLOWSTONE STUDY AREA

used for industrial purposes. Electric conversion can take place using wet or dry cooling towers, and with or without scrubbers. Different sites are considered for each plant, i.e. savings that might be realized through use of energy complexes were not evaluated. Each process has separate production costs and capacities.

4) Transportation from Processor to Consuming Region. For that coal which is converted to electricity in the Yellowstone Study Area, provisions are included in the model to transport the energy from the point of conversion to the demand point by transmission lines. Pipelines for transportation of synthetic gas were not included in the model because the activity forecast is handled exogenously.

Formulation of the linear programming model involved the combination of cost components into an overall cost equation, referred to as the objective function, and the preparation of a set of constraint equations. The matrix for this model includes 761 activities, 277 slack activities, 277 constraints, and has a density of 1.96 percent. The model was solved by use of a packaged program (FMPS) available on the Univac 1108 System. Solving the problem involves the search for an optimal solution (minimize total cost) which is feasible with respect to the given constraints (satisfies each constraint equation). The computer run time averages about 3 minutes with 30 seconds for optimization. Detailed documentation of the micro model is presented in Appendices A through E. Therefore, the discussion here is limited to a general overview.

Objective Function

The objective incorporated in the model is to minimize the total overall cost necessary to meet the demand conditions of the scenario being analyzed. The overall cost is the sum of the costs incurred in each of the activities involved in the process of meeting the demand for coal: mining, coal transportation, conversion to electricity or synthetic gas, electrical transmission. Reclamation fee and severance taxes are included in the mining costs; emission taxes are included in the conversion costs.

The objective function implies an overall view of the resources development of the study area since it includes

not only the costs of mining, transportation, and conversion, but also includes environmental cost components. Furthermore, it was developed from the overall viewpoint of a Federal, state or local policy maker or planner rather than that of a particular mine operator or utility. Therefore, the results should be interpreted from this perspective.

Constraints

The constraints represent the limitations and requirements that are imposed on the choice of activities which minimize the objective function, and stem from the physical, financial, environmental, legal, and demand considerations. The constraints include equations for material balance, demand, production capability, resources availability, and pollutant emissions. Each of these is described briefly below.

Material Balance. The material balance constraints are used to maintain an internal consistency in the model. They state that the input flow is equal to the output flow at any stage of the system. For example, the material balance constraints ensure that the coal mined in an area (input) is equal to the sum of (output): (1) the amount transported as coal to the demand regions; (2) the amount consumed in mine area thermal electric plants; and (3) the amount converted to synthetic gas in the study area.

Demand. These constraints state that the demand for electricity in each of the demand regions must be met by some combination of electricity produced either in the mining area or at the demand points. The demand for industrial coal in the demand regions must also be met.

Production Capability. Capacity limits are placed on the production capabilities of each type of mine and conversion facility. In a similar manner, capacity limits are imposed on the transportation linkages in the model. These limits are explained in more detail in the pertinent Appendices and in the description of the scenarios.

Resources Availability. Constraints also are placed upon the availability of coal reserves in each of the mining areas.

Pollutant emissions. The limits imposed upon the level of air and water pollutant emissions by State and Federal

regulations are reflected in the model by including the costs incurred in complying with those standards in the objective function.

Some constraints were handled exogenously. For example some coal reserves are located on lands where mining is not likely to occur because of environmental or other reasons. Consideration was given to the significance of reserves that occur (1) within one mile of the corporate limits of existing cities and incorporated towns; (2) under existing State and Federal highways; (3) on irrigated cropland; (4) on valley floors of major streams and tributaries, (5) in unique environmental areas such as local, State and National monuments, parks, forests, wildlife refuges, wild lands, and other units of the wilderness preservation system. The studies indicate that significant reserves occur in some of these areas, such as Custer National Forest in Mining Area No. 3 and on irrigated land in Mining Area No. 5. However, it was concluded that adequate reserves are available without disturbing these areas to support the levels of mining activities indicated by the PIES model (high regional energy development scenario) beyond the year 2000. Therefore, while the application of these land use constraints affects the pattern of mining development, it does not affect the total amount of coal that would be mined in the study area.

The forecast of the level of synthetic gas activity and the determination of the Yellowstone Study Area share of the coal production in PIES Coal Supply Regions 7 and 8 were also handled exogenously.

In the operation of the model, some constraints proved binding while others did not. Thus, it is possible to determine with the model which of the constraints are critical in the overall development of energy resources in the study area.

Linking The Macro and Micro Models

In the PIES model, coal from different supply regions is classified in four categories with respect to Btu content (14, 19, 22, and 24 million Btu per ton) and two categories with respect to sulfur content (low and high sulfur). These "supply" coals are shipped through a transportation network to nodes (Denver, Kansas City, Minneapolis-St. Paul, and

others) where they are converted, on a Btu basis, to "demand" coals. The "demand" coals have a Btu content of 22.5 Million Btu/ton and are divided into the three categories of industrial coal, low-sulfur utility coal, and high sulfur utility coal. A "split table" determines the distribution of demand coal available at each transhipment node to each neighboring demand region. The utility coal is then burned in power plants classified by age (existing or new), load factor (base or medium), and sulfur content of coal burned (low or high-sulfur).

The two models were interfaced by tracing coal from PIES Coal Supply Regions No. 7 and 8 through the PIES transportation network and determining, for each energy demand region, the demand for industrial coal (on a Btu basis) and for electricity generation (in Gwh/year) for each type of plant. Those demands were then used as an input in the micro-model through the demand constraints equations.

Because of (1) the proximity of Energy Demand Region 6 (West North Central) to the Yellowstone Study Area, and (2) the existence of several major load centers in the region at various distances from the Study Area, this region was divided into three subregions: Kansas City (6K), St. Louis (6L), and Minneapolis-St. Paul (6M). In accordance with the "split table" mentioned above, the demands for these regions were taken as 25, 35, and 40 percent, respectively, of the demands for Region 6.

Model Limitations

The model used in the micro analysis was designed to produce information for use in Level B or reconnaissance level water and related resources planning in the Yellowstone River Basin and Adjacent Coal Areas. The model provides results in sufficient detail and accuracy for this type of planning, but is not intended to be used for individual facility planning. A brief summary of the model limitations is presented here to avoid any misunderstandings about the models capabilities.

Because of the large scale of the systems being studied, generalizations had to be made of costs and constraint characteristics of the activities in the model. It should be recognized that a detailed analysis of a particular site may lead to somewhat different cost or constraint values. For example, the transportation costs of a particular train

movement may differ by site because of variations in operational characteristics and competitive conditions which have been generalized in this study. In a similar manner, generalizations have been made in mining, conversion, and other components of the model to achieve a relevant level of aggregation.

The assumption also has been made that energy development will occur in an economically rational manner, subject to the previously described constraints. In reality there are other factors that will influence the pattern of development. For example, there is considerable uncertainty about future State and Federal energy development policies. Changes in State taxes, environmental standards, and other such actions can radically influence development patterns. For this reason, a sensitivity analysis has been conducted to determine the influence on the study results of changes in a few of these key variables.

In summary, the interpretation of the results of micro analysis should be made in full view of the purposes it was designed to serve.

Regional Energy Scenarios

A summary of the assumptions made in defining the regional energy development scenarios is presented in this section. Additional details on each assumption are presented in the related appendix. For example, a discussion of transportation assumptions, capacities, and costs is presented in Appendix B, Transportation Capacity and Cost Analysis. As indicated previously, these scenarios are presented for use in subsequent plan formulation studies. They do not represent goals or recommendations.

High Scenario

The high regional energy development scenario provides an indication of the maximum contribution the study area might reasonably be expected to make in meeting national energy needs. In other words, the high scenario is primarily constrained by energy demands, as opposed to the most probable scenario, which is resource constrained. As such, the high scenario provides the direct link with the PIES forecast. The major assumptions underlying this scenario are:

1) Energy resources will be developed in an economically rational manner, subject to relevant technological, environmental, social, legal and institutional constraints.

2) Present taxation and environmental policies and regulations at both the State and Federal level will remain essentially unchanged into the future.

3) Capital for energy development will be forthcoming because the rate of return on investment will be sufficiently attractive and the corresponding risk sufficiently low. Similarly, wages will be high enough to attract sufficient labor with the appropriate skills.

4) The Yellowstone Study Area coal production will be equal to 85 percent of the total coal production from PIES Coal Supply Regions 7 and 8, as indicated by the macro analysis. Southern Wyoming and Colorado will retain their current share of 15 percent of this market.

5) Social and environmental problems associated with the rapid expansion of mining and other energy related activities in concentrated areas will limit the annual coal production capacity in each mining area. This limit was set at 100 million tons in 1985 and 200 million tons by the year 2000.

6) Mining will not occur (1) within one mile of the corporate limits of existing cities and incorporated towns; (2) under existing State and Federal highways; (3) on irrigated crop lands; (4) on valley floors of major streams and tributaries; and (5) in unique environmental areas such as local, state and national monuments, parks, forests, wildlife refuges, wild lands, and other units of the wilderness preservation system. Coal reserves on other lands, including Indian reservations, will be available for development.

7) The net available link capacities of existing railroad lines will be expanded to 40 million tons of coal per year by 1985 and 100 million tons per year by the year 2000. This would involve an upgraded single track system with centralized traffic control (CTC) by 1985, and alternating 10 miles of single track and 10 miles of double track with CTC by the year 2000.

8) Institutional, social and environmental obstacles to long distance coal slurry development will be removed in the near future. However, this alternative transportation mode will be used only when railroad capacities become saturated.

9) Necessary water supplies can be delivered on a timely basis to the point of demand at a cost of less than $450 per acre-foot.

10) Consequently, mechanical draft wet towers will be used for cooling of coal conversion plants (a cost of water delivered at the plant site in excess of $450 per acre-foot would make mechanical draft dry towers economically attractive).

11) There is no surplus capacity available in existing transmission facilities. New facilities will be necessary to transmit any additional electrical generation from the study area. Transmission of electrical energy by transmission lines is economically feasible with acceptable losses and without major operational problems up to a distance of approximately 1000 miles.

12) Financial incentives will be provided by the Federal Government to construct one coal gasification plant in the Yellowstone Study Area by the year 1985. Beyond 1990, the financial incentives program when coupled with dwindling domestic reserves of natural gas and oil will result in a rapid expansion of coal gasification activity. By the year 2000, resource availability, environmental concerns and social preferences, rather than economic demand, will act as the primary constraints on coal gasification activity in the study area.

Most Probable Scenario

The most probable regional energy development scenario is based on the same assumptions as the high scenario with the exception that institutional, social, and environmental obstacles are assumed to preclude long distance coal slurry development. Further, it is assumed that uncertainties regarding the amount of coal that will be moved by rail will preclude the large capital investments in fixed physical plant necessary to expand rail capacities beyond the levels assumed for the high scenario described above. It is anticipated that the controversy over the merits of coal slurry

pipelines versus rail development will continue for several years and the resulting impasse will constraint the capacity of both transportation modes.

Low Scenario

The low rate of regional energy development scenario is defined by the Scope of Investigations as including only production to meet local needs and to cover exports that are already guaranteed or highly probable. This production limit was established on the basis of the following assumptions:

1) "Exports that are already guaranteed or highly probable" are defined as those coal supplies contracted as of 1975, for shipment outside the three State study area in 1980. This amount to about 90 million tons per year (25).

2) Local needs are represented by the level of contract deliveries in 1980 for thermal-electric plants in Montana, Wyoming, and North Dakota that are considered already guaranteed or highly probable. Contracted deliveries for this area amounts to about 21 million tons of coal per year in 1980.

3) No significant amount of coal will be mined for household, commercial, and industrial uses within the area during the study period. The similar Northern Great Plains Resources Program forecasts indicate that household and commercial use will be insignificant over the study period in the Yellowstone Study Area and that only one million tons of industrial coal will be used in the area by the year 2000 (2, p. II-63).

4) No coal gasification will occur by the year 2000.

5) The increase in energy needs of the area above 1980 contract levels will be relatively insignificant.

Under these assumptions, annual mining capacity in the study area will expand to 111 million tons by the year 1980. There is no requirement for growth in mining capacity beyond the year 1980. Therefore, the resource requirements are at the same level in 1985 and 2000.

Results of Micro Analysis

The study results indicate that the amount of coal development in the Yellowstone Study Area in the years 1985 and 2000 will depend substantially upon State and Federal energy policies and regulations, and to a lesser extent on demands for fuel. The study area contains nearly half the Nation's known strippable coal reserves. A large share of these reserves have a low sulfur content which, under current air emission standards, permits the burning of this coal in thermal electric power plants without expensive sulfur removal processes. This provides an economic advantage to the Yellowstone Study Area compared with coal regions producing high sulfur coal. However, many of the high sulfur coal areas are located much closer to large energy demand centers, and therefore have a transportation advantage when compared with the Yellowstone Study Area. There also are low sulfur coal producing regions, such as Central Appalachia, which are capable of producing large quantities of coal. Energy policies that discourage coal production in the Yellowstone Study Area, such as high severance taxes on coal, would shift large amounts of production to these other producing regions. Policies that improve the study areas competitive position, such as those that would reduce transportation costs, would substantially increase the amount of Yellowstone coal production.

Most of the demand for Yellowstone Coal occurs at long distances from the supply area. Therefore, the economics of transportation and electricity transmission are a critical factor in the determination of the levels of coal production for the different mining areas. For example, the cost of coal transportation by unit train from the Yellowstone Study Area to the East North Central Demand Region (No. 4) is about $10 per ton, compared with the "selling price" at the mine of from $4.50 to $9.00 per ton. In other words, transportation accounts for from one-half to two-thirds of the delivered cost for coal at the distant points where most of the demand occurs.

Since the customer is ultimately purchasing energy (Btu's), high Btu coal has an economic advantage over low Btu coal when coal is being transported in physical form. However, coal can be converted to electricity or gas and transported by transmission lines and gas pipelines. Mine-mouth conversion and transport by electrical transmission lines is usually the most economical means of marketing the energy from coal with a low Btu content, especially lignite.

Detailed information about coal production and conversion in each mining area and the associated resource requirements under the three basic regional energy development scenarios is presented in Tables III-1 through III-3.

In interpreting these tables, it should be noted that the capacities indicated for the thermal-electric plant generation are only approximate. A thermal-electric plant of 250 MW capacity, used for base load generation, burns about one million tons of coal per year, which is a relatively small amount compared to the production of a mining area.

Under the most probable regional energy development scenario, the level of coal production in the Yellowstone Study Area is expected to increase from its 1975 level of 40 million tons per year to about 160 million tons per year in 1985 and 510 million tons per year in 2000.

Under the low scenario, production is expected to be about 110 million tons per year in both 1985 and 2000.

Under the high scenario, production would rise to about 300 million tons per year in 1985 and 800 million tons per year by the year 2000.

Coal Production and Disposition in the Yellowstone Study Area

Table III-4 summarizes the disposition of coal produced in each Yellowstone mining area under the low, most probable, and high regional energy development scenarios. The table indicates the amounts of coal transported from the Yellowstone Study Area, by transportation mode, to meet national energy demands by 1985 and 2000. It also indicates the amounts of coal used in the study area for conversion to electricity and synthetic gas under the scenarios cited above.

Table III-1. ENERGY ACTIVITIES, RESOURCE REQUIREMENTS AND AIR POLLUTANT EMISSIONS
MOST PROBABLE REGIONAL ENERGY DEVELOPMENT SCENARIO 1/

		North Dakota		Montana						Wyoming					
		Mining Area No. 1		Mining Area No. 2		Mining Area No. 3		Mining Area No. 4		Mining Area No. 5		Mining Area No. 6		Total Yellowstone Area	
	Units	1985	2000	1985	2000	1985	2000	1985	2000	1985	2000	1985	2000	1985	2000
MINES 2/	Total Number	3	23	4	6	0	8	17	40	7	25	1	1	32	103
Coal Production	Million Tons/Year	17.25	112.36	19.49	30.88	0	37.96	84.65	200	37.96	128.45	3.47	3.47	162.82	513.1
COAL GASIFICATION PLANTS 3/	Number of Units	1	8	0	0	0	4	0	0	0	3	0	0	1	15
Production	MCFD	250	2,024	0	0	0	1,000	0	0	0	790	0	0	250	3,814
THERMAL-ELECTRIC PLANTS 4/	Total Number	6	18	1	1	0	0	3	2	1	1	0	0	11	23
Megawatt-Capacity	Megawatt	2,914	9,182	50	50	0	0	1,369	1,370	390	390	0	0	4,723	10,992
Generation	Gigawatt-hr/year	9,191	41,766	158	158	0	0	8,395	7,001	2,393	2,393	0	0	20,136	51,317
WATER REQUIREMENTS 5/															
Mines	Acre-feet/year	345	2,247	390	618	0	759	1,693	4,000	759	2,569	69	69	3,256	10,262
Reclamation	" "	2,571	16,742	1,748	2,770	0	2,133	4,757	11,240	1,063	3,596	311	311	10,450	36,793
Coal Gasification	" "	9,986	80,469	0	0	0	40,014	0	0	0	31,588	0	0	9,986	152,071
Electric Generation	" "	22,978	104,415	394	394	0	0	20,987	17,502	5,982	5,982	0	0	50,341	128,293
Slurry Pipeline	" "	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	" "	35,879	203,872	2,532	3,783	0	42,906	27,437	32,742	7,804	43,735	381	381	74,033	327,419
LABOR REQUIREMENTS 6/															
Mines	Man x year/year	354	2,256	360	579	0	763	1,577	3,920	702	2,376	70	70	3,064	9,964
Coal Gasification	" "	624	5,029	0	0	0	2,502	0	0	0	1,974	0	0	624	9,505
Electric generation	" "	379	1,194	7	7	0	0	178	178	51	51	0	0	614	1,429
Total	" "	1,357	8,479	367	585	0	3,265	1,755	4,098	753	4,401	70	70	4,302	20,898
CAPITAL REQUIREMENTS															
Mines	Million dollars	48	505	74	112	0	213	364	1,016	187	651	10	10	685	2,508
Coal Gasification	" "	998	8,044	0	0	0	4,003	0	0	0	3,160	0	0	998	15,207
Electric Generation	" "	557	2,609	0	0	0	0	153	154	0	0	0	0	710	2,764
Total	" "	1,603	11,158	74	112	0	4,215	517	1,170	187	3,811	10	10	2,393	20,478
LAND REQUIREMENTS															
Strip-Mining Area	Acres/year	661	4,303	448	710	0	547	1,219	2,880	273	922	80	80	2,680	9,442
Sites															
Mines	Acres	518	3,371	585	927	0	1,139	2,539	6,000	1,139	3,853	104	104	4,885	15,393
Coal Gasification	"	499	4,024	0	0	0	2,001	0	0	0	1,579	0	0	499	7,605
Electric Generation	"	2,914	9,182	50	50	0	0	1,369	1,370	390	390	0	0	4,723	10,992
Total	"	3,931	16,577	635	977	0	3,140	3,908	7,370	1,529	5,823	104	104	10,107	33,990
AIR POLLUTANT EMISSIONS															
Particulates	Tons/year	5,611	29,065	79	79	0	4,070	4,197	3,500	1,196	4,405	0	0	11,084	41,120
Sulfur Oxides	"	66,291	340,402	946	946	0	44,688	50,369	42,006	14,356	49,601	0	0	131,962	477,643
Nitrogen Oxides	"	53,401	268,831	789	789	0	29,830	41,974	35,005	11,963	35,503	0	0	108,127	369,958

1/ Assumes an adequate water supply can be delivered on a timely basis to the point of demand at a cost of less than $450 per acre-foot.

2/ Based on average mine capacity at 5 million tons per year.

3/ Based on average unit capacity at 250 MCFD.

4/ Based on average plant size at 500 megawatts

5/ Consumptive use.

6/ Operating personnel only.

Table III-2. ENERGY ACTIVITIES, RESOURCE REQUIREMENTS AND AIR POLLUTANT EMISSIONS[1]

LOW REGIONAL ENERGY DEVELOPMENT SCENARIO

		NORTH DAKOTA		MONTANA						WYOMING				Total	
		Mining Area No. 1		Mining Area No. 2		Mining Area No. 3		Mining Area No. 4		Mining Area No. 5		Mining Area No. 6		Yellowstone Area	
	UNITS	1985	2000	1985	2000	1985	2000	1985	2000	1985	2000	1985	2000	1985	2000
MINES[2]	Total Number	6	6	1	1	0	0	6	6	11	11	1	1	25	25
Coal Production	Million Tons/Year	11	11	.5	.5	0	0	25	25	74	74	0.5	0.5	111	111
THERMAL ELECTRIC PLANTS[3]	Total Number	6	6	1	1	0	0	4	4	3	3	0	0	14	14
Megawatt Capacity	Megawatts	1222	1222	50	50	0	0	900	900	390	390	0	0	2562	2562
Gigawatt-hour/Year	Gigawatt-Hour/Year	7493	7493	307	307	0	0	5519	5519	2392	2392	0	0	15711	15711
WATER REQUIREMENTS[4]															
Mines	Acre-feet/Year	220	220	10	10	0	0	500	500	1480	1480	10	10	2220	2220
Reclamation	" " "	1639	1639	45	45	0	0	1405	1405	2072	2072	45	45	5206	5206
Coal Gasification	" " "	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Electric Generation	" " "	18733	18733	767	767	0	0	13797	13797	5979	5979	0	0	39276	39276
Slurry Pipeline	" " "	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total		20592	20592	822	822	0	0	15702	15702	9531	9531	55	55	46702	46702
LABOR REQUIREMENTS[5]															
Mines	Man-years/Year	220	220	10	10	0	0	500	500	1480	1480	10	10	2220	2220
Coal Gasification	" " "	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Electric Generation	" "	159	159	7	7	0	0	117	117	50	50	0	0	333	333
Total	" "	379	379	17	17	0	0	617	617	1530	1530	10	10	2553	2553
CAPITAL REQUIREMENTS															
Mines	Million Dollars	26	26	0	0	0	0	0	0	295	295	0	0	321	321
Coal Gasification	" "	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Electric Generation		0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	" " "	26	26	0	0	0	0	0	0	295	295	0	0	321	321
LAND REQUIREMENTS															
Strip Mining Area	Acres/Year	421	421	12	12	0	0	360	360	531	531	12	12	1336	1336
Sites															
Mines	Acres	494	494	7	7	0	0	846	846	2264	2264	0	0	3611	3611
Coal Gasification	"	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Electric Generation	"	1222	1222	50	50	0	0	900	900	390	390	0	0	2562	2562
Total		1716	1716	57	57	0	0	1746	1746	2654	2654	0	0	6173	6173
AIR POLLUTANT EMISSIONS															
Particulates	Tons/Year	733	733	30	30	0	0	541	541	233	233	0	0	1537	1537
Sulfur Oxides	" "	6110	6110	250	250	0	0	4510	4510	1940	1940	0	0	12810	12810
Nitrogen Oxides	" "	611	611	25	25	0	0	451	451	194	194	0	0	1281	1281

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[1] Assumes an adequate water supply can be delivered on a timely basis to the point of demand at a cost of less than $450 per acre-foot

[2] Actual number of plant[illegible]

[3] Actual number of m[illegible]

[4] Consumptive use

[5] Operating personnel only

Table III-3. ENERGY ACTIVITIES, RESOURCE REQUIREMENTS AND POLLUTANT EMISSIONS
HIGH REGIONAL ENERGY DEVELOPMENT SCENARIO 1/

		NORTH DAKOTA		MONTANA						WYOMING					
		Mining Area No. 1		Mining Area No. 2		Mining Area No. 3		Mining Area No. 4		Mining Area No. 5		Mining Area No. 6		Total Yellowstone Area	
	Units	1985	2000	1985	2000	1985	2000	1985	2000	1985	2000	1985	2000	1985	2000
MINES 2/	Total Number	11	32	1	6	6	40	20	40	20	40	1	1	59	159
Coal Production	Million Tons/Year	54.1	158.26	7.1	30.1	29.2	200	100	200	100	200	3.47	3.47	293.9	791.8
COAL GASIFICATION PLANTS 3/	Number of Units	1	10	0	0	0	6	0	0	0	5	0	0	1	21
Production	MCFD	250	2,524	0	0	0	1,500	0	0	0	1,330	0	0	250	5,354
THERMAL-ELECTRIC PLANTS 4/	Total Number	18	18	1	1	0	0	2	2	1	1	0	0	21	21
Megawatt-Capacity	Megawatt	8,870	8,873	50	50	0	0	900	900	390	390	0	0	10,210	10,214
Generation	Gigawatt-hr/year	34,198	40,806	158	158	0	0	5,521	5,521	2,393	2,393	0	0	42,270	48,878
WATER REQUIREMENTS 5/															
Mines	Acre-feet/year	1,082	3,165	142	602	584	4,000	2,000	4,000	2,000	4,000	69	69	5,877	15,837
Reclamation	" "	8,060	23,580	637	2,700	1,640	11,240	5,620	11,240	2,800	5,600	311	311	19,068	54,671
Coal Gasification	" "	9,986	100,828	0	0	0	60,021	0	0	0	53,044	0	0	9,986	213,893
Electric Generation	" "	85,494	102,015	394	394	0	0	13,804	13,804	5,982	5,982	0	0	105,674	122,194
Slurry Pipeline	" "	11,365	15,191	0	10,851	0	73,518	24,376	26,563	22,982	23,314	0	0	58,724	149,437
Total	" "	115,987	224,779	1,173	14,547	2,224	148,779	45,800	55,606	33,764	91,940	381	381	199,329	556,032
LABOR REQUIREMENTS 6/															
Mines	Man x year/year	1,091	3,300	131	563	540	3,975	1,870	3,920	1,850	3,700	70	70	5,552	15,529
Coal Gasification	" "	624	6,302	0	0	0	3,752	0	0	0	3,315	0	0	624	13,369
Electric Generation	" "	1,153	1,153	7	7	0	0	117	117	51	51	0	0	1,327	1,328
Total	" "	2,868	10,755	138	569	540	7,728	1,987	4,037	1,901	7,066	70	70	7,503	30,225
CAPITAL REQUIREMENTS															
Mines	Million dollars	225	775	18	108	152	1,109	446	1,016	505	1,020	10	10	1,357	4,039
Coal Gasification	" "	998	10,079	0	0	0	6,004	0	0	0	5,307	0	0	998	21,390
Electric Generation	" "	2,510	2,508	0	0	0	0	0	0	0	0	0	0	2,510	2,508
Total	" "	3,733	13,362	18	108	152	7,113	446	1,016	505	6,326	10	10	4,865	27,936
LAND REQUIREMENTS															
Strip-Mining Area	Acres/year	2,072	6,061	163	692	420	2,880	1,440	2,880	718	1,436	80	80	4,893	14,029
Sites															
Mines	Acres	1,623	4,748	213	903	876	6,000	3,000	6,000	3,000	6,000	104	104	8,815	23,755
Coal Gasification	"	499	5,042	0	0	0	3,002	0	0	0	2,652	0	0	499	10,696
Electric Generation	"	8,870	8,873	50	50	0	0	900	900	390	390	0	0	10,210	10,214
Total	"	10,992	18,663	263	953	876	9,002	3,900	6,900	3,390	9,042	104	104	19,525	44,665
AIR POLLUTANT EMISSIONS															
Particulates	Tons/year	18,114	30,655	79	79	0	6,105	2,761	2,761	1,196	6,585	0	0	22,150	46,185
Sulfur Oxides	"	216,331	357,363	946	946	0	67,032	33,129	33,129	14,356	73,541	0	0	264,762	532,011
Nitrogen Oxides	"	178,435	279,211	789	789	0	44,745	27,607	27,607	11,963	51,493	0	0	218,794	403,845

1/ Assumes an adequate water supply can be delivered on a timely basis to the point of demand at a cost of less than $450 per acre-foot.

2/ Based on average mine capacity at 5 million tons per year.

3/ Based on average unit capacity at 250 MCFD.

4/ Based on average plant size at 500 megawatts

5/ Consumptive use.

6/ Operating personnel only.

Table III-4

COAL PRODUCTION AND DISPOSITION IN 1985 AND 2000 BY MINING AREA FOR LOW, MOST PROBABLE AND HIGH SCENARIOS

Scenario and Disposition	Annual Coal Production by Mining Area (Million Tons)						
	North Dakota	Montana			Wyoming		
	1	2	3	4	5	6	Total
1985 and 2000 Low							
Transport by Rail	5.5	0.4	0	21.9	72.6	0.5	100.9
Transport by Slurry Pipeline	0	0	0	0	0	0	0
Convert to Electricity in Study Area	5.5	0.1	0	3.1	1.4	0	10.1
Convert to Gas in Study Area	0	0	0	0	0	0	0
Total	11	.5	0	25	74	0.5	111
1985 Most Probable							
Transport by Rail	0	19.4	0	80	36.5	3.5	139.4
Transport by Slurry Pipeline	0	0	0	0	0	0	0
Convert to Electricity in Study Area	6.9	0.1	0	4.6	1.5	0	13.1
Convert to Gas in Study Area	10.3	0	0	0	0	0	10.3
Total	17.2	19.5	0	84.6	38.0	3.5	162.8
2000 Most Probable							
Transport by Rail	0	30.8	0	196	105.0	3.5	330.8
Transport by Slurry Pipeline	0	0	0	0	0	0	0
Convert to Electricity in Study Area	29.4	0.1	0	4	1.5	0	35
Convert to Gas in Study Area	83	0	38	0	26.5	0	147.5
Total	112.4	30.9	38	200	128.5	3.5	513.3
1985 High							
Transport by Rail	0	7.0	0	56.3	60.3	3.5	127.1
Transport by Slurry Pipeline	19.2	0	29.2	40.6	38.2	0	127.2
Convert to Electricity in Study Area	24.6	0.1	0	3.1	1.5	0	29.3
Convert to Gas in Study Area	10.3	0	0	0	0	0	10.3
Total	53.8	7.1	29.2	100.0	100.0	3.5	283.9
2000 High							
Transport by Rail	0	11.9	28.7	152.6	115.2	3.5	311.9
Transport by Slurry Pipeline	25.6	18.1	114.3	44.3	38.8	0	241.1
Convert to Electricity in Study Area	28.6	0.1	0	3.1	1.5	0	33.3
Convert to Gas in Study Area	104.	0	57	0	44.5	0	205.5
Total	158.2	30.1	200	200	200	3.5	791.8

The level of coal mining activity in each area is determined by the model on the basis of economic criteria (cost minimization) and constraints such as those imposed by coal reserves, social and environmental limitations, and capacities of transportation and processing systems (feasibility).

For example, the coal reserves constraints limit the annual mining rate to ensure a thirty-year mine life based on demonstrated strippable reserves; and social and environmental constraints limit production in each mining area to 100 million tons per year in 1985 and 200 million tons per year in 2000 (see scenario description).

The critical factors in the development of the mining areas can be determined by analyzing the binding or non-binding character of these constraints under the various scenarios.

In the following discussion the most competitive areas will be presented first.

Coal from mining area 6, Wyoming Powder River Subbituminous, has the lowest "selling price" per Btu in the study area (see Appendix A) but the limited reserves (46 million tons) preclude any large-scale development.

Mining area 5, Wyoming Powder River lignite, contains very large reserves (10 billion tons) with a Btu content of 16.4 million Btu/ton, a low overburden ratio and the second lowest "selling price" per Btu in the study area.

Reserves in area 4, Montana Powder River Subbituminous, are 2.7 billion tons for low overburden ratio coal, and 12 billion tons for medium overburden ratio coal, with a Btu content of 17.4 million Btu per ton. The mining cost is the lowest in the study area but higher taxes in Montana cause the "selling price" per Btu to be higher than that in area 5.

A savings in transportation costs associated with high Btu content can partially offset the difference in "selling price" at the mine; for this reason the costs per Btu delivered at the demand points of coal from areas 4 and 5 are very close. Therefore, the relative level of development of mining areas 4 and 5 is determined primarily by the economics and capacities of the transportation system in the absence of other constraints.

Because of the high competitiveness of coal from these areas, they represent the majority of coal production from the study area; however, development is constrained by transportation capacities in the most probable scenario and by social and environmental limitations in the high scenario.

Coal from mining area 3, Montana Powder River Lignite, has the same mining cost and "selling price" per ton as coal from mining area 4 but a lower Btu content. This area also shares transportation facilities with areas 4 and 5. Development occurs in the area only when coal production in mining areas 4 and 5 has reached its upper limit. No constraints are binding except under the year 2000 high scenario (social and environmental constraints).

The low Btu content of lignite from North Dakota (mining area 1) and Eastern Montana (mining area 2), 13.74 and 13.4 million Btu per ton respectively, makes long distance transportation of this coal uneconomical thus development generally takes place in the form of processing in areas close to the mine.

No rail transportation of North Dakota lignite occurs in the model under the most probable and high scenario because the railroad line serving this area is used at full capacity to ship coal from area 4. Development of the Eastern Montana Lignite, which has a higher "selling price" per Btu than North Dakota Lignite, occurs mostly under the most probable scenario and to much lesser extent under the high scenario, and is due to the possibility of shipping coal from area 2 to Minneapolis-St Paul over railroad line 1 through Minot, which represents transportation capacity not available to other areas (see Appendix B). No shipment to other destinations was allowed on this light duty line.

Under the high scenario slurry pipelines are available to transport coal when the rail transportation facilities from areas 1 and 2 are at capacity. Shipment of North Dakota Lignite to Demand region 4 thus occur under the 1985 and 2000 high scenario when production of the more competitive coal producing areas have reached the limits represented by the social and environmental constraints and rail network capacity. Less coal is produced in area 2 under the high scenarios than in area 1, since this coal is less competitive and area 1 has available transportation capacity. Under all scenarios the total conversion activity consumes most of area 1 coal production. In the year 2000, conversion to

synthetic gas represents the largest part of the conversion activity. Since physical movement of North Dakota lignite is relatively expensive, the development of the area will be strongly influenced by local, State and Federal legislation regarding coal conversion activities.

Transportation and Transmission Systems

Transportation capacities are a critical constraint on energy development in the Yellowstone Study Area under both the "most probable" and "high" scenarios. With the recent growth in coal production, present transportation modes (i.e. rail and electrical transmission lines) are already approaching the limit of existing capacities. The type and location of capacities expansions will have a profound influence on energy development patterns in the study area.

Appendix B contains a detailed description of the transportation network of the LP model. Therefore, the following discussion is limited to an overview of the assumptions and the analysis of their influence on the study results.

Under both the most probable and high regional energy development scenarios, it was assumed that an upgraded single track rail system with centralized traffic control[1/] will be available on existing lines by 1985. By the year 2000, it was assumed that alternating single and double tracks (10 miles single - 10 miles double) with centralized traffic control will be installed on existing lines. Unit trains with an operating capacity of 10,000 net tons each are expected to move utility coal to the demand regions. Conventional trains are expected to continue hauling the smaller quantities of industrial coal.

Transmission lines from generating plants located in the Study Area to demand regions are expected to be alternating current (AC) for distances up to 500 miles. For distances over 500 miles, direct current (DC) circuits of about 600 KV are assumed. It was further assumed that the technical problems and substantial energy losses associated with transmission lines longer than about 1,000 miles would make them uneconomical. Therefore transmission lines are used in the model to transmit power generated in the Study Area only to the Mountain Region (Energy Demand Region 8) and the Kansas City and Minneapolis - St. Paul subregions (Energy Demand Subregions 6K and 6M).

Under the high regional energy development scenario, it is assumed that institutional, social and environmental obstacles to slurry pipeline construction will be removed in the near future. However, it is assumed that this alternate transportation mode will be used only when the railroads are operating at full capacity.

The amounts of coal that would be transported from the Yellowstone mining areas by rail and coal slurry pipelines in the years 1985 and 2000, under the energy development scenarios and assumptions used in this analysis, are reported in Table III-4. All of the coal would be shipped by rail under the low and most probable scenarios. Under the high scenario, coal demands would exceed the assumed rail capacities, resulting in the construction of 5 long distance coal slurry pipelines with an average annual coal transportation capacity of 25 million tons each by the year 1985. By the year 2000, the member of coal slurry pipelines would increase to 10.

Coal would also be transported by unit train-waterway combinations under the three regional energy development scenarios. Since this alternative has no significant influence on resource demands in the Yellowstone Study Area, this traffic is combined with the unit train shipments.

Conversion Plants

Thermal Electric

The capacity and generation of coal-fired thermal electric plants in the Yellowstone Study Area, by mining area for the years 1985 and 2000, are presented for the three scenarios in Tables III-1 through III-3. It should be noted that the linear programming model sites thermal electric generating capacities either in the mining areas that produce the coal or in the demand regions. Generating capacity and resource requirements for the thermal electric plants located outside the Yellowstone Study Area are not included in the reported data.

If coal is transported from one mining area to another within the Yellowstone Study Area, the generating capacity and the corresponding resource requirements are reported in the mining area where the coal is obtained. For example, the capacities of plants located along the Yellowstone River

in Montana are reported in Mining Area No. 4 (Powder River Basin Subbituminous) which is their source of coal.

Under the most probable scenario, the Yellowstone Study Area capacity of coal fired thermal electric plants would be about 4,700 megawatts (MW) in 1985 and 11,000 MW by the year 2000. The corresponding number of plants would be about 11 in 1985 and 23 by the year 2000. The large amount of electrical generation in the study area in the year 2000 occurs primarily because of the anticipated limits on the capacity to transport coal to the demand region.

Under the high scenario, coal slurry pipelines are assumed to be available and the amount of coal production increases substantially but the amount of anticipated generating capacity by the year 2000 is slightly less than under the most probable scenario. The Yellowstone Study Area capacity of coal fired thermal electric plants would be about 10,200 MW in the year 1985. The corresponding number of plants would be about 21, which is ten more than under the most probable scenario. But beyond 1985, there is no increase in anticipated study area generating capacity. Instead the increased coal production is transported by both slurry pipelines and railroad for conversion in the demand regions.

Coal Gasification

The PIES forecast and other estimates developed for this study indicate that the cost of producing synthetic natural gas will likely exceed the cost of energy from other sources through the year 1990. Therefore, no coal gasification activity is forecast for the Yellowstone Study Area on the basis of purely economic criteria. However, FEA assumes in the 1985 Reference Case that financial incentives will be provided for synthetic fuel development of 880 million barrels per day oil equivalent in the U.S. This incentive program is expected to result in the construction of one coal gasification plant in the Yellowstone Study Area by 1985 under both the high and most probable regional energy development scenarios. No coal gasification activity is anticipated under the low scenario.

Beyond 1990, the financial incentives program coupled with dwindling domestic reserves of natural gas and oil are expected to result in a rapid expansion of coal gasification

activity. A total of 15 coal gasification plants with a capacity equivalent to 3,814 million cubic feet per day (MCFD) of pipeline quality gas are projected to be constructed in the Yellowstone Study Area by the year 2000 under the most probable scenario. Under the high scenario, a total of 21 units are anticipated with a capacity equivalent to 5,354 MCFD.

Resource Requirements and Pollutant Emissions

The energy related resource requirements in the Yellowstone Study Area for water, labor, capital, and land in the years 1985 and 2000 for the low, most probable, and high regional energy development scenarios are summarized in Tables III-1 through III-3. These resource requirements are presented by mining area for mining, coal conversion, and slurry pipeline activities. Estimates are also provided of the total pollutant emissions associated with these activities and which could be quantitatively determined.

An understanding of the concept of economic demand and supply, and the relationship of these energy studies to the overall Yellowstone Level B Study is essential to the proper interpretation and application of the information in these tables.

The resource requirements presented in Table III-1 through III-3 represent the quantities of water and other resources that entrepreneurs would be willing to buy under the various assumptions made in the analysis regarding prices and other variables. The requirements determined in this study served as inputs to a comprehensive river basin study being conducted by the Missouri River Basin Commission (MRBC). Analyses of resource supplies and resource requirements for other purposes such as irrigation, fish, wildlife, and recreation are being developed by other participants in the Yellowstone Level B Study. The task of relating overall resource demands to sources of supply is beyond the scope of the present study. This will be accomplished in subsequent plan formulation studies by the MRBC Yellowstone Study Team.

Water costs were changed parametrically in order to determine the relationship of energy-related water requirements to prices. These studies along with parametric analysis with respect to key parameters and assumptions are summarized below under the section on "Sensivity Analysis".

The water requirements reported in Tables III-1 through III-3 are based on the assumption that necessary water supplies can be conveyed to the site at a delivered cost of less than $450 per acre foot. This is the cost above which dry-cooling towers become economically attractive. The water quantities are reported in acre-feet of consumptive use. Requirements are included for mining operations, reclamation, coal fired thermal electric plants, coal gasification plants, and coal slurry pipelines.

Labor requirements are reported on the basis of the number of operating personnel in man-year equivalents. Construction labor, which is temporary in nature, and is heavily affected by construction scheduling, is not included in the analysis.

Land requirements are reported on the basis of the number of acres for the years 1985 to 2000. This approximates the total amount of land devoted to conversion sites, mine sites, and non-productive stripped areas at these points in time. Reclaimed land is not included, but a separate estimate is provided of the annual amount of land strip-mined in 1985 and 2000. Since it takes about 3 to 5 years to reclaim land that has been strip-mined, the amount of land under reclamation at any given time is approximately 3 to 5 times the annual stripping area. Land requirements for transportation facilities were not included because these would depend to a significant extent on development in the non-energy sectors of the economy.

Capital requirements represent the cumulative construction cost at 1975 price levels of all new mines and coal conversion facilities in operation by the years 1985 and 2000. However, the model does not indicate when old facilities will be phased out of operation or precisely when construction of new facilities will begin. Since capital requirements are based on additional operating capacities, there may be some replacements of existing facilities that are omitted from the estimate. The amount of understatement would be relatively minor since all major facilities will be new and have useful lives extending beyond the period of analysis. A more precise estimate of capital requirements could be derived by considering the economic life of existing facilities and scheduling new construction so the capacities indicated by the model will be available in the years 1985 and 2000. Such refinements are regarded as unwarranted in view of the study objectives. Capital shortages as cons-

traints on development are usually symptomatic of other problems such as high risk or institutional obstacles. The capital required for economic development is ordinarily forthcoming if the rate of return on investment is sufficiently attractive and the corresponding risk sufficiently low.

Numerical estimates are provided of air emissions including particulates, sulfur oxides (SO_x), and nitrogen oxides (NO_x). These estimates are summarized by mining area in Tables III-1 through III-3. Other emissions were considered qualitatively and are discussed in Appendix D - Air and Water Quality Considerations.

Under the most probable scenario, the Yellowstone Study Area annual air emissions in 1985 for particulates, sulfur oxides, and nitrogen oxides would be about 11,100 tons, 132,000 tons, and 108,100 tons, respectively per year. By the year 2000, these emissions would increase to 41,100 tons, 477,600 tons and 370,000 tons per year respectively because of the substantial increases in coal conversion capacities.

Under the high scenario, the year 1985 emissions would be about double the levels for the most probable scenario because the amount of thermal electric generation is greater. In the year 2000, the emissions under the high scenario would be approximately 10 percent greater than under the most probable scenario.

Sensitivity Analysis

A sensitivity analysis was conducted using the LP model to determine the influence on the study results of changes in key parameters or assumptions. This analysis illustrates the usefulness and flexibility of the LP model as a policy planning tool. It demonstrates how the model can be used to evaluate the consequences of alternate policies and plans as well as changing technologies or economic conditions.

Parameters and assumptions considered in the analysis include: (1) delivered price of water; (2) severance or other such taxes on coal production; (3) policies prohibiting the siting of additional coal conversion plants in the study area; (4) Colorado and Southern Wyoming share of coal produced in PIES Coal Supply Regions 7 and 8; (5) State

imposed limits on coal development in North Dakota; and (6) rail transportation network.

The results of this sensitivity analysis are discussed below. The summary tables of the corresponding computer runs are included in Appendix E.

Water Cost

A parametric analysis was conducted to determine the influence of water cost on the quantity of water required under the 1985 most probable scenario. The cost of delivered water was increased from zero to $1,000 per acre-foot, while keeping the model solution both optimal and feasible. The transportation constraints on the movement of coal prevented the shifting of significant amounts of electrical generation from the study area to the demand regions. However, as the delivered cost of water increases, dry cooling methods for coal conversion plants become more economically attractive compared with wet cooling methods. The savings in water use (0.3 acre-feet per GWH for dry cooling versus 2.5 acre-feet per GWH for wet cooling) eventually offset both the additional capital cost and the increase in coal consumption associated with dry cooling.

For new, base load coal-fired thermal electric plants, mechanical draft dry cooling towers becomes economically preferable to mechanical draft wet cooling towers at a delivered water cost of about $450 per acre-foot. For intermediate load plants, the breaking point is at about $750 per acre-foot.

The water requirements associated with various delivered water costs for mining and coal conversion activities under the 1985 most probable scenario are shown on Table III-5. Water requirements for the Yellowstone Study Area are reduced by nearly one-fourth as water costs increase from less than $450 per acre-foot to between $750 and $1,000 per acre-foot. It should be noted that the potential for reduction in water use by thermal electric plant was limited by the fact that existing plants were not provided the option of switching from wet to dry cooling methods, and they represent more than one-half of the total capacity in the 1985 most probable scenario (2,500 MW out of 4,700 MW).

Table III-5

DEMAND SCHEDULE FOR WATER
YELLOWSTONE STUDY AREA,
1985 MOST PROBABLE SCENARIO

Delivered Water Price ($/Acre-Foot)	Water Consumption (Acre-feet/year)		
	Electrical Generation	Other Use	Total
0 to 450	50,000	25,000	75,000
45 to 750	44,000	25,000	69,000
750 to 1000	32,000	25,000	57,000

State Taxes

Taxes in North Dakota, Montana and Wyoming were successively increased in a parametric procedure from zero to $10 per ton above their current level.

Collective or individual increases in severance taxes tend to shift coal production to supply regions outside the Yellowstone Study Area, as discussed in the macro analysis, but result in relatively limited production shifts among mining areas in these States under the most probable scenario. In the 1985 most probable scenario, the development of coal resources is severely constrained by transportation capacities. This is confirmed in the linear programming analysis by the high value of the dual variables associated with the railroad capacity constraints (the dual variable represent the value of an additional unit of rail capacity). Because nearly all the available transportation links are fully utilized, the ability to shift coal production from one mining area to another within the Yellowstone study area is limited.

Although a parametric analysis was not conducted for the year 2000 most probable scenario, the same situation as for the 1985 analysis can be anticipated. Transportation capacity constraints limit shifts in production within the Yellowstone Study Area, so the primary influence of increased taxes on coal would be to shift production to other coal supply regions. However, significant production shifts within the study area would be possible under the high

scenario since slurry pipelines are available to provide additional transportation capacities.

Non-Conversion Policy

The influence of the adoption of a non-conversion policy was tested by eliminating activities corresponding to new thermal-electric plants and coal gasification plants. Slurry pipeline transportation was assumed available in the year 2000, but not in 1985. Since the coal gasification forecast is exogenous and the amount of coal used for conversion in thermal-electric plants in the mining areas is a relatively small portion of the total, the flows corresponding to coal exported from the study area remain virtually constant and the coal mining activities are reduced by an amount equivalent to the consumption of coal gasification plants and new thermal-electric plants in the basic runs.

Conversion activities, however, are water-intensive. Therefore a significant decrease in water consumptive use was obtained from 74,000 Acre-feet per year to 43,000 Acre-feet per year in 1985 and from 550,000 to 250,000 Acre-feet per year in 2000.

Increase of the Share of Colorado and Southern Wyoming

The 2000 high scenario was run with coal production from mining areas 8 and 9 representing 25% of the coal production of PIES coal supply regions 7 and 8 instead of the 15% assumed under the base run. The production of the Yellowstone Study Area decreased from 790 million tons to 675 million tons. The decrease in production affected only mining areas 1, 2 and 3, while mining activity in 4, 5, and 6, where the most competitive coals are found, remained at its upper limit.

Constraint on Development in North Dakota

The year 2,000 most probable scenario was run with a limitation of total lignite production in North Dakota at about 39 million tons per year, and the synthetic gas activity set at its 1985 level, 10 million tons per year, corresponding to one 250 MCFD plant.

Under the base run the production in North Dakota is 112 million tons, of which the synthetic gas activity represents 83 million tons, and industrial and utility use 29

million tons. Under this modified year 2000 scenario, the total production of North Dakota lignite is 39 million tons per year, of which 29 million tons is for industrial and utility use and 10 million tons for synthetic gas activity. Therefore, the activities in other coal producing areas remain essentially constant.

Under this modified scenario the water requirements in mining area 1 are reduced from 200,000 acre-feet per year to 120,000 acre-feet per year, and the land use for mine and conversion sites is reduced from 16,500 acres to 11,000 acres.

Alternative Rail Transportation Network

The influence of the assumptions on the transportation network are shown by the changes of the results of the four runs caused by the use of an alternative transportation network described in detail in Appendix B.

This alternate network allows less flexibility in the use of railroad lines; therefore the development of the mining areas with the most competitive coal is more severely constrained and the model has to use less economical coal from other areas to meet the demands. It is noteworthy that this increased use of coal with a lower BTU content led to a decrease in the capacity of the railroad system in terms of BTU's for the same capacity in million tons per year, and this caused a significant increase in thermal-electric generation in the mining areas.

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TECHNICAL APPENDICES

APPENDIX A

MINING ANALYSIS

Detailed studies were made of both coal and uranium resources within the Yellowstone Study Area and the Project Independence Evaluation System (PIES) Coal Supply Regions Nos. 7 and 8. This appendix summarizes the results of these studies and documents the coal mining data used in the linear programming model. Detailed supporting information is on file at the Harza office in Chicago.

Coal Studies

The general approach used in the coal mining analysis involved (1) dividing the PIES Coal Supply Regions No. 7 and 8 into fourteen relatively homogeneous coal mining areas, (2) evaluating the coal reserves in each of these mining areas, and (3) estimating the costs of mining and coal selling prices in those areas with significant potential for development. Separate estimates of mining costs were developed for various overburden ratios using an engineering cost analysis approach. The estimated selling prices for coal reserves with various overburden ratios formed the basis of the coal supply functions in the linear programming model.

Mining Areas

Exhibit 4 in Chapter III, Micro Analysis, shows the 12 homogeneous coal mining areas identified in PIES Coal Supply Regions Nos. 7 and 8. These areas are listed below:

1. North Dakota Lignite

2. Eastern Montana Lignite

3. Montana Powder River Lignite

4. Montana Powder River Subbituminous

5. Wyoming Powder River Lignite

6. Wyoming Power River Subbituminous

7. Wyoming and Montana Marginal Coal Fields
8. Colorado Coal Fields
9. Southern Wyoming Coal Fields
10. South Dakota Marginal Coal Fields
11. Northeastern Utah Coal Fields
12. Eastern Idaho Coal Fields

The homogenous coal mining areas were delineated on the basis of state boundaries, physiographic basin, and rank of coal. The division between lignite and subbituminous coals was set at 8,300 Btu per pound of coal. All coals with average heat values below 8,300 Btu/lb were classified as lignite when delineating the coal mining areas, in accordance with standard D-388 of the American Society for Testing Materials, "Standard Specification for Classification of Coals by Rank".

Mining Areas 1 through 7 are within the boundary of the Yellowstone Study Area. Mining Areas 8 through 12 are outside the Yellowstone Study Area, but are within the PIES Coal Supply Regions Nos. 7 and 8. Consideration of Mining Areas 8 through 12 was necessary because the regional coal demands available from the "Macro Analysis" are reported on the basis of PIES Coal Supply Regions. By including the reserves and costs of all the significant mining areas in the linear programming model, it was possible to disaggregate the PIES data and identify the Yellowstone Study Area share of regional demands.

Coal Reserves

The Yellowstone Study Area contains about 70 billion tons of demonstrated strippable reserves. This reserve tonnage is large enough to support all projected mining rates for the region through the year 2000.

On the basis of the coal reserve analysis, it was determined that Mining Areas 1 through 6, 8, and 9 have significant potential for coal development during the years 1985 and 2000. Estimates of the demonstrated strippable reserves in these areas are summarized in Table A-1. All reserve data were taken from official reports and newsletters from the U.S. Geological Survey, U.S. Bureau of Mines, and State Geological Surveys (References 47 through 61 in Bibliography).

Table A-1

SUMMARY OF COAL RESERVES BY MINING AREA AND OVERBURDEN RATIO

Mining Area	Type of Coal and Overburden Ratio	Demonstrated Strippable Reserves (Billion tons)	Low Sulfur Reserves (Percent)
1	North Dakota Lignite		33
	0-5	3.689	
	5-10	0.453	
	> 10	-	
2	Eastern Montana Lignite		87
	< 1	0.833	
	1-5	2.741	
	5-10	1.907	
3	Montana Powder River Lignite		88
	< 1	1.869	
	1-5	11.815	
	5-10	2.460	
4	Montana Powder River Subbituminous		91
	< 1	2.663	
	1-5	12.390	
	5-10	7.764	
5	Wyoming Powder River Lignite		90[2] to 99
	< 1	10.360[2]	
	1-5	10.568[2]	
	5-10	0.788	
6	Wyoming Powder River Subbituminous		97
	< 1	0.011	
	1-5	0.018	
	5-10	0.017	
8	Colorado Coal Fields	10.357	100
9	Southern Wyoming Coal Fields	1.549[1]	18

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[1] Strippable Reserves for Hanna Basin and Green River Fields.

[2] Wyodak-Anderson Seam.

The reserves were classified with respect to their sulfur content, overburden ratio and seam thickness.

Sulfur Content

Only Coal which is permissible for use as fuel in thermal electric power plants under current air pollution standards was included in the estimates of low sulfur reserves. Present Federal air pollution standards limit stack emissions for power plants to 1.2 pounds of SO_2 per million Btu of coal burned in the boilers. The sulfur emitting qualities of coal depend upon the Btu value and the tendency of the coal to retain sulfur in the ash.

An approximate formula for calculating sulfur emissions from power plant stacks is as follows (62):

$$S = \frac{2 \times 10^4}{B} [\bar{X} - \frac{32 \times 10^{-2}}{80} (\bar{X}_{ash} \times \bar{X}SO_3)]$$

where

S = pounds of SO_2 emitted per million Btu of coal burned.

$\bar{X}$ = sulfur content of the coal by weight (percent)

B = Btu value of the coal (Btu per lb)

$\bar{X}_{ash}$ = ash content of coal by weight (percent)

$\bar{X}_{SO_3}$ = sulfur trioxide content of coal ash (percent of ash)

A review of coal analyses for the Yellowstone study area indicated $\bar{X}$ ash and $\bar{X}SO_3$ content to average about 6 percent and 10 percent, respectively.

Overburden Ratio

The overburden ratio indicates the cubic yards of waste material which must be removed to strip mine one ton of coal. In order to calculate the ratio, a stratigraphic column of waste and coal must be considered. The total volume of waste includes only overburden when single coal seams are mined, but also includes interburden in the case of multiple seams. The unit weight of coal is 1.08 tons per

cubic yard, and overburden weights about 1.00 ton per cubic yard. Therefore, the ratio of total thickness of waste to that of coal divided by 1.08 is the overburden ratio. In this appendix the unit weight of coal was rounded to one ton per cubic yard, so the thickness ratio is equivalent to the overburden ratio. As a simplification for this analysis, the unit weight of coal was rounded from 1.08 to 1.00 ton per cubic yard so that the overburden ratio would be equivalent to the thickness ratio.

Seam Thickness

For North Dakota and Eastern Montana Lignite, coal seams are relatively thin, being generally less than 15 feet. Dragline operations are the predominant method of stripping.

In the Powder River Basin of Montana and Wyoming, some coal seams are over 40 feet thick, reaching as thick as 125 feet in the Wyodak-Anderson seam. For very thick seams, strip mining by dragline is not feasible because presently available machines are not able to cast the stripped overburden material clear of the wide pits required. Therefore a truck-and-shovel method of stripping is used.

In the study area, so much coal is available with favorable overburden ratios that significant amounts of underground mining appears unlikely in the next few decades. Underground mines are relatively expensive and require more lead time to develop. In addition, there are potential problems in developing underground mines in most of the study area because of weak rock strata above and below the coal seams.

Mining Costs and Coal Selling Prices

Coal mining costs and selling prices were estimated for the eight mining areas with significant reserves. Separate estimates were made for various ranges of overburden ratio. The estimated coal mining costs and selling prices are summarized in Table A-2. Coal selling prices are defined as the mining costs plus administrative costs, royalties, state severance taxes, other state taxes, Federal income tax, and net income. A summary of current state taxes affecting coal mining in the study area is presented in Table A-3.

Mining cost estimates were based primarily upon information gained from visits to four operating strip mines in the

Table A-2

SUMMARY OF COAL MINING COSTS AND SELLING PRICES

Mining Area	Type of Coal and Overburden Ratio	Mining Cost[1] $/Ton	Selling Price[2] ($/Ton)
1	North Dakota Lignite		
	0-5	3.83	6.68
	5-10	4.50	7.69
	> 10	5.83	9.67
2	Eastern Montana Lignite		
	< 1	3.18	6.97
	1-5	4.10	8.93
	5-10	5.82	12.60
3	Montana Powder River Lignite		
	< 1	2.82	6.21
	1-5	3.40	7.45
	5-10	5.66	12.25
4	Montana Powder River Subbituminous		
	< 1	2.82	6.21
	1-5	3.40	7.45
	5-10	5.66	12.25
5	Wyoming Powder River Lignite		
	< 1	3.15	5.10
	1-5	4.15	6.67
	5-10	5.66	9.04
6	Wyoming Powder River Subbituminous		
	< 1	2.82	4.58
	1-5	3.40	5.49
	5-10	5.66	9.04
8	Colorado Coal Field	5.46	7.46
9	Southern Wyoming Coal Fields	4.81	7.55

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[1] Cost estimates are based on a typical mine capacity of 5 million tons per year.

[2] Based on current tax levels.

Table A-3

CURRENT STATE TAXES AFFECTING COAL MINING IN YELLOWSTONE STUDY AREA

State	Severance Tax	Property Taxes	Other Taxes	Notes
NORTH DAKOTA	50¢/ton plus 1¢/ton for every 3 point increase in Wholesale Price Index. In 1975 the tax was 52¢/ton.	Tax is based on one-half the mill levy applied to assessed value of property, structures and coal. Average local mill levy equals 183. Tax estimated at 8.15% of Gross Income.	Income Tax is 6% of Net Income. Amounts to 1% of Gross Income.	
MONTANA	BTU/lb. — Surface[1] under 7,000 — 12¢/ton or 20% of value 7,000-8,000 — 22¢/ton or 30% of value 8,000-9,000 — 34¢/ton or 30% of value over 9,000 — 40¢/ton or 30% of value Use basis which yields greater amounts. Use 5,000 ton/quarter exemption.	Gross Proceeds Tax equals 45% of taxable value of gross coal production multiplied by local mill levy. Taxable value equals gross value of coal production less Severance Tax, Resource Indemnity Tax, and Gross Proceeds Tax from previous year. Mill levy is 155 to 165. Tax estimated at 6.2% of Gross Income.	Resource Indemnity Trust Tax (1/2 of 1% of Gross Income). Income Tax (6.75%) of Net Income). Estimated at 1% of Gross Income.	In calculating severance tax, other taxes are deductible. Therefore, the tax rate amounts to about 21.8% of the Gross Income from surface mined coal.
WYOMING	4% of Gross Income	Ad Valorem Tax is 60 mills per dollar of coal sales or 6% of Gross Income.	Coal Impact Tax. Estimated at 2% of Gross Income.	

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[1] Value equals gross income less allowable deductions.

area, which served as model mines for the study. These mines were the Wyodak Mine near Gillette, Wyoming; the Colstrip Mine of Western Energy Resources at Colstrip, Montana; the Absaloka Mine of Westmoreland Resources near Hardin, Wyoming; and the Glenharold Mine of Consolidation Coal Company near Stanton, North Dakota.

Cost estimates were made for five separate coal deposit conditions based upon operating conditions at the mines visited. These operating conditions are listed in Table A-4. Overburden was considered to be weak and easily broken into strippable material with limited drilling and blasting.

Two of the mines listed in Table A-4 show mining development in separate phases. These phases, reflect anticipated increases in overburden ratio and mine capacity over the period of analysis.

The total mining costs represent the sum of separate cost estimates for each of the following functional categories:

1. Stripping
2. Coal Extraction
3. Reclamation
4. Plant and Shop Operation
5. Salaries and Overhead
6. Exploration and Development
7. Union Welfare Fund

Stripping costs are a major cost component and are highly correlated with overburden ratio. The relationship between total mining cost and overburden ratio for five million ton per year strip mines is shown for three different seam categories in Table A-5. The 10 to 20 ft seam category represents coals in North Dakota and Eastern Montana Lignites, the 20 to 40 ft seam category represents coals in the Powder River Basin in both Montana and Wyoming, and the 80 ft seam category represents the Wyodak-Anderson seam in Wyoming.

Table A-4

OPERATING DATA FOR MODEL MINES
YELLOWSTONE STUDY AREA

Model Mine	Location	Annual Production (Million tons)	Total Overburden and Interburden (feet)	Total Coal (feet)	Overburden[1/] Ratio (Average)	Number of Seams	Method of Stripping
1	Mining Areas 1 or 2, N. Dakota - Wyoming	3.3	94	16.5	5.7:1	3	Dragline
2	Mine Areas 3 or 4, Montana						
	Phase I	5.0	75	38	2.0:1	2	Dragline
	Phase II	10.0	120-150	58	2.5:1	3	Dragline
	Phase III	15.0	120-150	58	2.5:1	3	Dragline
3	Mining Areas 3 or 4, Montana						
	Phase I	4.0	70	25	2.8:1	1	Dragline
	Phase II	6.6	100	25	4.0:1	1	Dragline
4.	Mining Areas 4 or 6, Montana-Wyoming	10.0	50-100	25	2.8:1	1	Dragline
5	Mining Area 5, Wyoming	10.0	80	80	1.0:1	1	Truck-and-Shovel

1/ Overburden ratio is approximated by total thickness of overburden and interburden divided by total thickness of coal, assuming a unit weight for coal of one ton per cubic yard.

Table A-5

MINING COST AS A FUNCTION OF OVERBURDEN RATIO AND SEAM THICKNESS

Overburden Ratio	Mining Cost ($/ton) 10 to 20 ft seam	20 to 40 ft seam	80 ft seam
0	3.00	2.55	2.66
1	3.17	2.81	3.64
2	3.34	3.11	4.62
3	3.49	3.40	5.60
4	3.64	3.72	
5	3.82	4.10	
6	4.02	4.54	
7	4.31	5.14	
8	4.63		
9	5.15		
10	5.82		

Coal selling prices were calculated from mining costs using the following formula:

$$\frac{P}{C} = \frac{100}{(100 - R - Ts_1 - Ts_2 - I)}$$

Where:

P = Coal selling price ($/ton)

C = Mining cost plus administration costs ($/ton)

R = Royalty payment (9.3%)

Ts_1 = State severance tax (%)

Ts_2 = Other state taxes (%)

and I = Expected Net Income before Federal income tax as a percentage of the coal price.

Administration costs are estimated at $0.10 per ton of coal. Royalty payments are for the right to extract coal from Federal land. Similar payments would be made to landowners if mineral rights were leased from private individuals. A rate of 9.3 percent of gross income is assumed for both situations in this analysis.

Severance taxes and other state taxes vary from one state to another. Therefore, provisions have been made in the linear programming (LP) model for the explicit analysis of alternative state tax programs. For the initial runs of the LP model, it was assumed that the current tax structure will continue through the period of analysis. A sensitivity analysis was then conducted to determine the influence on the study results of variations in state taxes. The results of this sensitivity analysis are reported in Chapter III.

Expected net income before Federal income taxes is estimated at 15 percent of the selling price for coal.

Resource Requirements Associated with Coal Mining

Other information generated by the model mine studies relating to associated future land, labor, capital and water requirements are listed by State in Table A-6. These data are averages of more detailed information used in the LP model.

Land use refers to the annual amount of land stripped to produce one million tons of coal. Mining the thinner seams in North Dakota involves much more land surface disruption than mining the thick Wyodak-Anderson seam in Wyoming.

Labor productivity is normally quoted in tons per man-day in the mining industry. The coefficients presented in Table A-5 are stated inversely in man hours per ton. This allows a direct estimate of labor needs once total tonnage in a mining area is known. Only operating labor is included in the coefficients.

Capital investment is the money required by a mining company to plan, design and construct a strip mine. The capital investment coefficient in Table A-6 multiplied by the mine capacity in tons per year provides an estimate of the total capital required to establish a mine.

Water use is broken down into mine use and reclamation use. For strip mines, water is mainly used for dust control on roadways, general plant and shop use, and for potable water supply. For reclamation, the water use is for the re-establishment of vegetation.

Table A-6

AVERAGE RESOURCE REQUIREMENTS ASSOCIATED WITH COAL MINING1/

Resource	Units	North Dakota	Montana			Wyoming	
		Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Land							
Stripping Area	Acres/million tons	38.3	23.0	14.4	14.4	7.2	23.0
Labor							
Productivity	Man-year equivalent/ million tons	24.0	20.5	20.5	20.5	18.5	20.5
	Man-hours/ton 2/	0.048	0.041	0.041	0.041	0.037	0.041
Cost 3/	$/Ton	0.58	0.49	0.49	0.49	0.44	0.49
Capital Investment	$/ton of annual capacity	8.30	4.80	5.70	5.70	5.15	5.70
Water Use4/							
Mining Operations	Acre-feet/million tons	20	20	20	20	20	20
Reclamation Use5/	Acre-feet/millions tons	149	90	56	56	23	90

1/ Based on representative mine capacity of 5 million tons/year. Actual inputs into the L.P. model also vary with the overburden ratio.

2/ Based on 2,000 hours/Man-year.

3/ Based on $12/hour labor cost.

4/ Consumptive use.

5/ Corresponds to 3.89 Acre-feet/acre over a three-year period.

Uranium Studies

The presently known uranium resources in the three-state area are concentrated in Wyoming, both in the Powder River Basin and at the southern edge of the Wind River Basin. Wyoming accounts for 32 percent of the proven U.S. uranium reserves; 20 percent of the Wyoming reserves are located in the Powder River Basin.

Uranium supplies for nuclear generation are secure through the mid-1980's from measured reserves and probable reserves. Past the mid-1980's the reserve base is not proven.

Uranium exploration, mining, and milling activities are expected to increase in the Powder River Basin in Wyoming and perhaps Montana during the next decade. There also are possibilities for development in the Wind River Basin and the Big Horn Basin.

Uranium Reserves

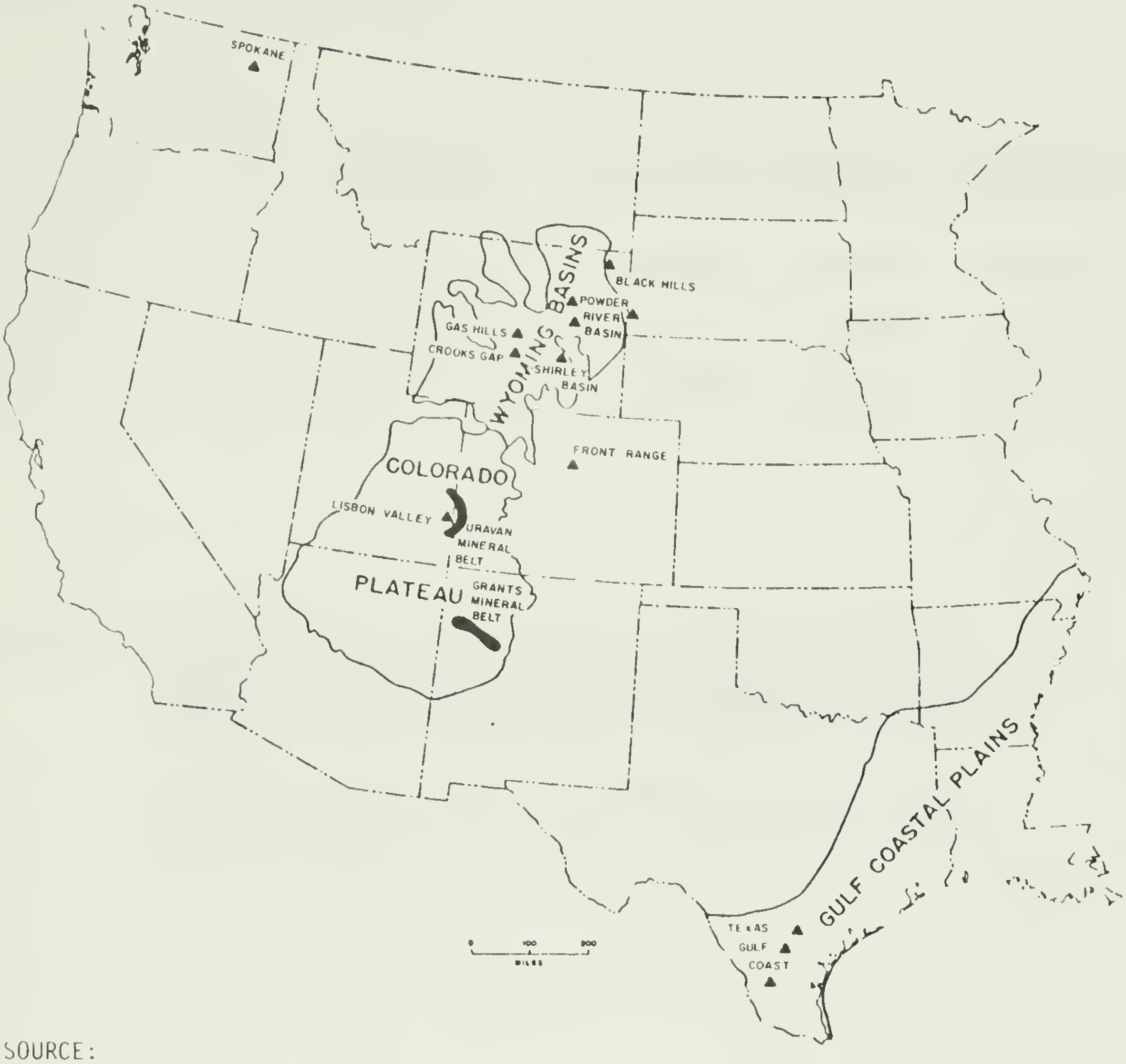
In the United States the main source of uranium has been stream-laid sandstones in Colorado, Utah, New Mexico, Wyoming and South Dakota. The deposits vary from flat-lenticular or podlike bodies to linear bodies with crescent shaped cross sections. Deposits mined to this date have ranged in grade from 0.1 to 0.3 percent U_3O_8, with some deposits reaching 0.5 percent.

Uranium in lignites also occurs in Western South Dakota, Southwestern North Dakota and Eastern Montana. Grade varies from 0.001 to 1.0 percent U_3O_8. However, the higher grade deposits tend to be small and isolated, so no mining for uranium in these areas is now in progress. Some uranium was mined from lignites in North Dakota during the 1960's.

The present principal uranium districts in the United States are shown in Exhibit A-2. The three major mining districts are the Wyoming Basins District, the Uravan Mineral Belt in Colorado and Utah, and the Grants Mineral Belt in New Mexico. Other mining areas are on the Texas Gulf Coast and near Spokane, Washington.

Estimated reserves for the Wyoming Basins Districts are summarized in Table A-7. In that table reserves are quoted in terms of "Forward Cost Category" in dollars per pound of U_3O_8. Forward cost is defined as amortized capital costs plus operating costs required for mining and milling the ore, but not including "sunk costs" for exploration, land acquisition, and mine-mill development.

EXHIBIT A-1



SOURCE:
Meehan, R.J."Uranium Reserve and Exploration Activity",
ERDA, Uranium Industry Seminar. October 7-8, 1975

PRINCIPAL URANIUM DISTRICTS OF THE UNITED STATES

Table A-7

URANIUM RESERVES IN WYOMING BASINS DISTRICT

Forward Cost Category	Tons U_3O_8			
	Discovered Reserves	Undiscovered (Potential)		
		Probable	Possible	Speculative
\$10/lb.	102,000	160,000	160,000	160,000
\$15/lb	190,000	265,000	265,000	265,000
\$30/lb.	216,000	313,000	84,000	31,000

Sources: Bowyer, Ben, "Quantity and Quality of Data Available on Potential Resources of Uranium", Mineral Resources and the Environment, National Academy of Sciences, 1975, Washington, D.C.

Hetland, D.L. "Potential Resources" Uranium Industry Seminar, Oct. 7-8, 1975 ERDA, Grand Junction, Colorado, pp. 105-120.

Exploration to find new reserves is presently very active in Wyoming. Drilling in the southern portion of the Powder River Basin is particularly active and should increase over the next few years. Many companies look to this area for future mine-mill development. Drilling can also be expected in the northern areas of the Powder River Basin, the Wind River Basin, and the Big Horn Basin.

Production Centers

In 1975, Wyoming accounted for 32 percent of U.S. uranium production. Wyoming produced 3,800 tons of U_3O_8 from ore with a grade of 0.14 percent U_3O_8. Of this production, it is estimated that 1,100 tons of U_3O_8 came from the Exxon operation in the Southern Powder River Basin area and 380 tons from the Gas Hills area.

Table A-8 shows a list of uranium mills which operated in 1975. Only one mill operated in the Yellowstone Study Area, and two operated in the Gas Hills area.

Resource Requirements for Uranium

A summary of resource requirements and mining costs for uranium mines and mills is presented in Table A-9. These data are for typically sized units. Nominal capacity is stated on the basis of tons of ore per day. Labor productivity is presented in tons of ore per man-day of operating labor. Land use is in acres for each site. Water Requirements are on the basis of acre-feet of consumptive use per year for each typical mine or mill. For open pit mines, water is used for dust control, vehicle maintenance, and potable use. For underground mining, water for drilling must be added. For milling operations, water is used for leaching and its associated processes, and as potable water. In addition mill tailings are normally transported to dumps by slurry pipelines. Water pumped from the mining pit or from the underground mines usually supplies enough water to meet mine and mill requirements.

Table A-8

U.S. URANIUM ORE PROCESSING MILLS WHICH OPERATED IN 1975[1]

Company	Location	Nominal Capacity (tons of ore per day)
Anaconda Company	Grants, New Mex.	3,000
Atlas Corporation	Moab, Utah	1,500
Conoco & Pioneer Nuclear Inc.	Falls City, Texas	1,750
Cotter Corporation	Canon City, Colo.	450
Dawn Mining Company	Ford, Washington	500
Exxon, U.S.A.	Powder River Basin, Wyo.	2,000
Federal-American Partners	Gas Hills, Wyo.	950
Kerr-McGee Corp.	Grants, New Mexico	7,000
Rio Algom Corp.	La Sal, Utah	500
Union Carbide Corp.	Uravan, Colo.	1,300
Union Carbide Corp.	Natrona County, Wyo.	1,200
United Nuclear-Homestake Partners	Grants, New Mexico	3,500
Utah Int'l Inc.	Gas Hills, Wyo.	1,800
Western Nuclear, Inc.	Jeffery City, Wyo.	1,200
	Total	27,850
Petrotomics Company, Shirley Basin, Wyoming (on standby)		(1,500)
	Total	29,350[2]

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[1] Source -- Energy Research and Development Administration (ERDA)

[2] Equivalent to approximately 18,000 short tons U_3O_8/yr.

Table A-9

SUMMARY OF RESOURCE REQUIREMENTS AND MINING COSTS FOR URANIUM MINES AND MILLS

	Nominal Capacity tons/day)	Labor Productivity (tons/man-day)	Water Requirements (acre-ft/yr)	Land Use (acres)	Capital Cost ($/ton of capacity)	Operating Cost ($/ton)
Open Pit Mine	500	25	200	300	$1,000	$ 9.50
Underground Mine	200	6	1/	100	1,500	13.50
Leach Mill	2,000	15	1/	280 2/	8,900	8.83

1/ Not estimated. In most cases water pumped from the mine is sufficient for the mill leaching operations.

2/ Includes 250 acres for waste area.

Impact of Uranium Mining in Yellowstone Study Area

The uranium mining industry appears to be capable of meeting fuel demands from the electrical power industry at least through the 1980's. Detailed studies performed by the Federal Energy Administration (FEA) and the Energy Research and Development Administration (ERDA) indicate, however, a distinct gap between expected nuclear powerplant needs and proven and probable reserves in the 1990's and beyond. Due to the long lead times required to find and mine uranium ore, continued uranium exploration will be necessary.

Uranium mine and mill expansion will take place where uranium ore reserves are found. Unlike coal deposits, which tend to be spread over large areas, the typical uranium deposit tends to be small and difficult to find.

Of the presently known uranium districts, the Gas Hills area has already been extensively drilled, so present reserves should not increase greatly. Some new mine development may occur, but existing mill capacity is expected to be adequate to handle production.

For the Southern Powder River Basin, exploration will undoubtedly be very active and mine and mill development will occur. It is estimated that mine production and mill capacity will double by 1985.

Beyond 1985, new reserve discoveries could profoundly influence uranium production in the study area. It is also possible that other areas in the Yellowstone Study Area could develop into active uranium districts. The water requirements associated with such development would be relatively low. The primary effects of concern in a Level B planning study would be the social and environmental impacts.

APPENDIX B

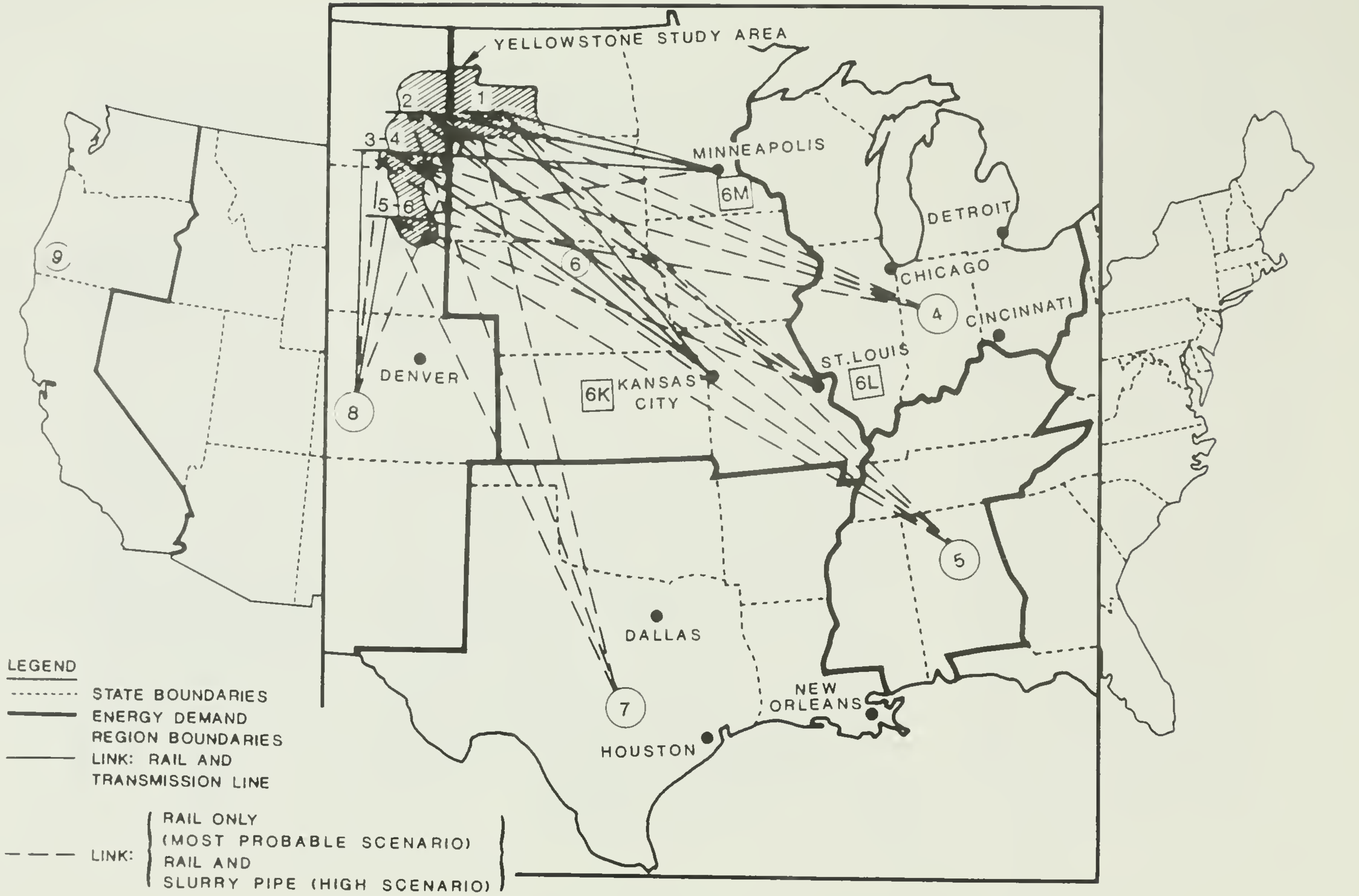
TRANSPORTATION CAPACITY AND COST ANALYSIS

This Appendix documents the procedures used to develop the information that describes the generalized transportation network by which energy is moved from the Yellowstone Study Area to the demand regions. Six possible methods exist for the movement of energy from the Yellowstone Study Area to points of demand. Four of these methods involve the transportation of coal to demand points and include: conventional rail shipment, unit trains, unit train-waterway combinations, and slurry pipelines. The fifth method involves coal fired generation of electricity in the Yellowstone Study Area and transmission of electrical energy to demand regions over high voltage transmission lines. The sixth system includes conversion of coal to high quality gas and distribution of the synthetic gas to demand regions by pipeline.

The transportation and transmission network of the LP model is shown in Exhibit B-1. Conventional rail and unit train transportation link every mining area to all energy demand regions. Transmission lines link the mining areas to load centers within 1,000 miles of the mining areas. Slurry pipelines link the mining areas to all significant demand points of over 1,000 miles distance. The distribution of high quality synthetic gas in a pipeline network to the demand regions was not modeled. The level of the conversion to gas activity in each mining region was forecast exogenously, and the distribution costs of that activity were included in the plant investment costs (Appendix C).

Each mining area, within which all activity takes place, is linked as shown in Figure B-1 to demand regions by one or more modes of transport, and for each of these modes, cost and capacity data were developed for use in the micro model. All energy developed within a mining area, is required by the constraint equations of the micro model to be transported as coal via a rail link (one or more types may be available to an area), or as electricity via a transmission link. Thus the total cost of energy arriving in a demand region from a mining area includes transportation. Another set of constraint equations place capacity limits on each link such that the total use by one or more mining areas can not exceed the appropriate limit.

EXHIBIT B-1



TRANSPORTATION NETWORK OF MICROMODEL

YELLOWSTONE ENERGY STUDY

HARZA ENGINEERING COMPANY · DECEMBER 1976

Railroad Capacity

The capacity of a railroad track depends upon numerous factors including the number of tracks, track condition, type of signal system, location and size of passing sidings, gradient and curvature of the track, terminal characteristics, presence of passenger trains, directional split of the traffic, and type of traffic. To determine the exact capacity of a particular railroad link is a complex process and requires extensive operating data. However, estimates can be made with a precision commensurate with "Level B" (reconnaissance level) planning requirements and objectives by using less detailed procedures. These procedures are documented below.

1) Theoretical capacity by rail type. The theoretical capacity, in trains per day, of each type of line was determined from values given by the Federal Railroad Administration for various signal and track combinations. These combinations included single, alternating single and double, or double track with signaled or centralized traffic control (CTC) signal systems. The theoretical capacity, presented in Table B-1, represents an upper limit on the number of trains that can operate per day over a particular line. In many cases, the practical capacity may be only one-third to one-half of the theoretical capacity. The daily capacity was converted to an annual capacity by assuming a 365 day year with half of the trains (those moving toward the demand regions) operating full at 10,000 net tons (100 cars at 100 net tons each) each and the other half (those returning to the mining areas) operating empty. Under these conditions a line capacity of one unit train per day corresponds to 1.83 million tons of coal per year.

   The net available theoretical capacity for a railroad line can be determined by subtracting the present amount of traffic on the line from the theoretical capacity, using traffic flow data available from the Federal Railroad Administration. Present flows were used with the assumption that non-coal flows over the railroad lines being analyzed will not have dramatic long run changes from their present levels over the period of analysis. This is in keeping with past experiences

Table B-1

CAPACITY VALUES FOR RAILROADS BY TYPE OF TRACK AND SIGNAL SYSTEM

Type of Track	Signal System	Theoretical Capacity (trains/day)	Probable Capacity (trains/day)	Net Available Capacity	
				trains/day	million tons/yr
Single Track	Unsignaled	30	15	12	22
Single Track	CTC 1/	60	28	22	40
Alternating 10-10 2/	CTC 1/	100	65	55	100
Double Track	CTC 1/	160	100	90	165

1/ Centralized traffic control

2/ Alternating 10 miles single track, 10 miles double track

and expectations for the future in the railroad industry. It should be noted, however, that recent growth in coal traffic from the Yellowstone Study Area is already beginning to approach the capacity of the railroad links in the area. In response to this problem, the Burlington Northern Railroad has announced a $990 million expansion program involving fixed plant improvements and the purchase by 1980 of some 1,000 new locomotives and about 3,250 new coal cars, in addition to an anticipated 18,000 cars to be purchased by the utility companies.

2) Probable capacity by rail type. A second method of determining the capacity for each track type resulted in what is referred to as "probable capacity." An analysis was made of the U.S. transportation zone maps in other regions with heavy coal traffic to determine maximum flows over each type of track. Based on this information, estimates were made of the probable capacity of each link type between the mining areas and demand regions. The net available capacity of each line then was determined by subtracting current flows over the line. The estimated probable capacities and net available capacities for different track and signal combinations are shown in Table B-1.

3) Capacity constraint equations. Railroad traffic between the mining areas and the demand regions is constrained by the combined capacity of the links in the network with the lowest net available capacity. These constraints were almost always in the vicinity of the coal mines since traffic could be dispersed to an increasing number of alternate paths as it moved farther beyond the point of origin. Given the information from steps 1 and 2, equation specifying the railroad capacity constraints on coal movements by rail were written. These equations state that the combination of traffic flowing from the mining areas to the demand regions cannot exceed the capacity of each railroad line. The flow over a particular line may be the result of a number of origin-destination combinations. These flows were identified in the equation.

> For both the high and most probable energy development scenarios, it was assumed that the railroad line capacities will be expanded to 40 million net tons in 1985 by upgrading existing track and using centralized traffic control. By the year 2000, it was assumed that line capacities will be expanded to 100 million net tons by installing alternating centralized traffic control.

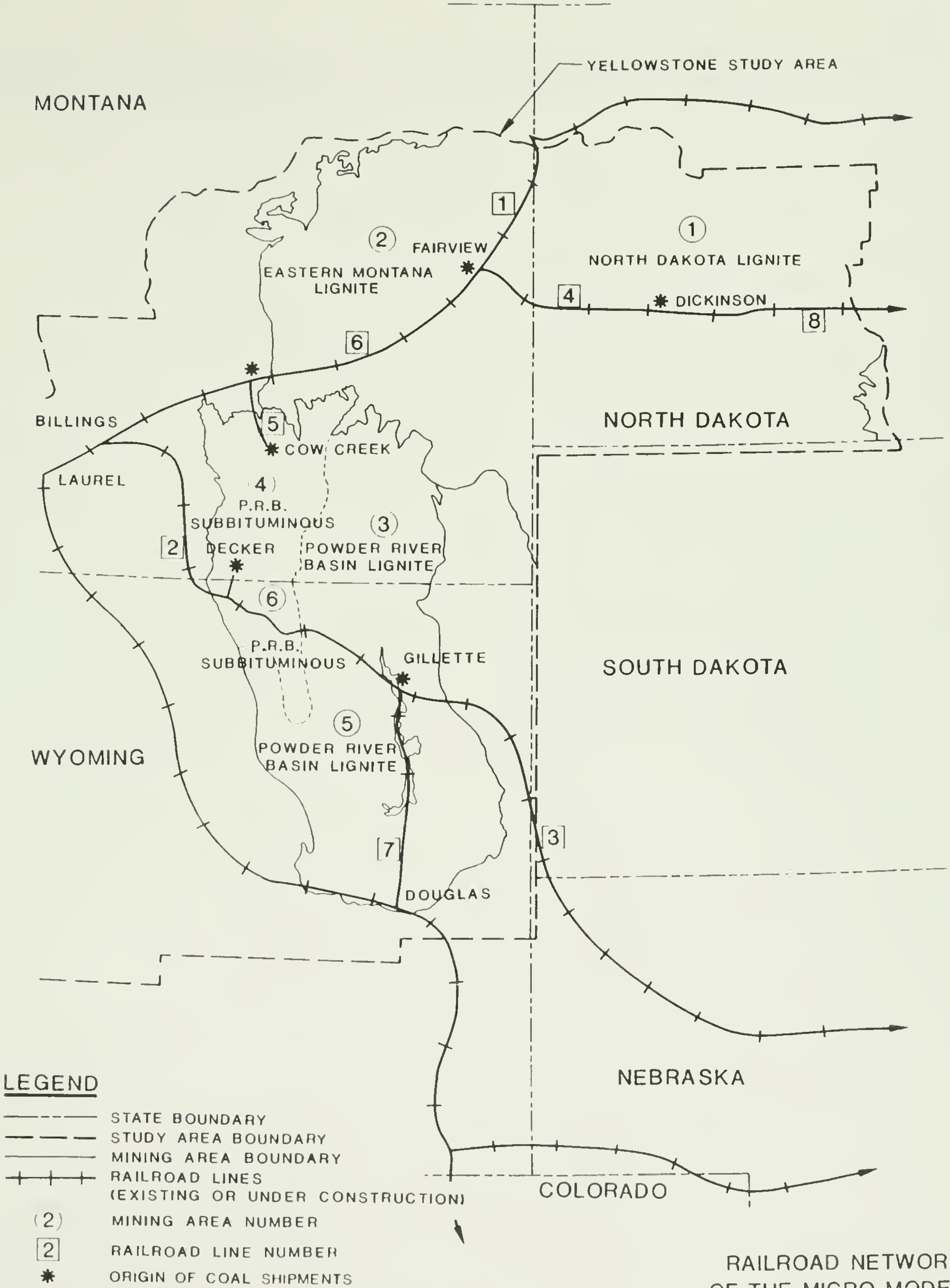
Exhibit B-2, shows the various railroad lines in the Yellowstone Study Area. In addition to the existing railroad network, a line is currently proposed in Wyoming between Gillette, and Douglas. This line would connect the Burlington Northern line through Gillette (Line number 3 on Exhibit B-2) and the Chicago and North Western (C & NW) line through Casper, allowing development of the existing or planned mines along its route. It was assumed that this line will be completed by 1985 and it is included in the model as line number 7.

The railroad transportation links of the LP model use appropriate lines, or combinations of lines, for shipment of coal. The various lines used to link mining areas and demand regions in the rail transportation network are summarized in Table B-2. The numbers in the table correspond to rail lines as identified in Exhibit B-2. Where practical, rail traffic can use alternate lines. For example, coal from mining areas 3 and 4 can be transported to the East North Central Demand Region (No. 4) either through the southern route on lines 2 and 3 or through the northern route on lines 4,5,6 and 8. Coal from mining areas 5 and 6 can use either line 3 or line 7.

Rail line 1 from Minot is light duty and no significant capacity increase is planned according to information obtained in personal contacts with Burlington Northern (BN) officials. Therefore, this line was used only for shipment of coal from mining area 2 to Minneapolis - St. Paul (6M).

In the runs described as "Alternative Rail Transportation Network" in the "Sensitivity Analysis" section of Chapter III, a different transportation network was used. It was assumed that the line between Gillette, Wyoming and Douglas, Wyoming would not be constructed. Rail line 7 represented the existing Billings-Laurel-Douglas track and Rail line 1 was assumed to be upgraded to the same capacity as the other lines. No alternate routings were considered

EXHIBIT B-2



RAILROAD NETWORK
OF THE MICRO-MODEL

for the transportation links. The lines linking the mining areas and demand regions in this alternate rail transportation network are summarized in Table B-3.

Table B-2

RAIL LINES CONNECTING MINING AREAS AND DEMAND REGIONS IN LP MODEL 1/

Origin by Mining Area (No.)	Destination by Demand Region						
	4	5	6K	6L	6M	7	8
1	8	8	8	8	8	8	2,4,6,7
2	4,8	4,8	2,3,6	4,8	1	2,6,7	2,6,7
3 and 4	2,3 or 4,5,6,8	2,3		2,3 or 4,5,6,8	4,5,6,8	2,7	2,7
5 and 6	3 or 7	3 or 7	3 or 7	3 or 7	3 or 7	7	7

1/ Numbers in table correspond to railroad lines as identified in Exhibit B-2.

Table B-3

ALTERNATE NETWORK OF RAIL LINES CONNECTING MINING AREAS AND DEMAND REGIONS 1/

Origin by Mining Area (No.)	Destination by Demand Region						
	4	5	6K	6L	6M	7	8
1	8	8	8	8	8	8	4,6,7
2	1	1	1	1	1	1	6,7
3 and 4	4,5,6,8	4,5,6,8	4,5,6,8	4,5,6,8	4,5,6,8	4,5,6,8	5,7
5 and 6	3	3	3	3	2,4,6,8	3	3

1/ Numbers in table correspond to railroad lines as identified in Exhibit B-2.

Waterway Capacity

All transport of coal by waterway would involve an initial movement of the coal by rail to a rail-water transfer terminal. The transportation analysis indicates that the capacity of the system is limited primarily by the rail component in the vicinity of the mining areas. The runs of the model presented herein reflect this situation.

Transmission Line Capacity

The number and voltage level of transmission lines to transmit power from coal fired generating plants in the mining areas to the demand regions were determined on the basis of the capacity of the generating plants and the involved distance. It was assumed that no surplus capacity will be available in existing transmission facilities.

Three levels of capacity to be transmitted were assumed for each link in the network. These included 1,600 MW, 3,200 MW, and 9,000 MW. Transmission distances were computed as the straight line distance from the generating plant site to a major distribution point located near the geographic center of the demand region, plus 10 percent to allow for terrain.

For distance up to 500 miles, AC transmission lines were used at either 765 KV or 1100 KV depending on the power to be transmitted. For distances over 500 miles, ± 600 KV DC circuits were used. In each case, the voltage level and number of circuits were selected so that the desired load could be met with one circuit out of service.

Coal Slurry Pipeline Capacity

The only long-distance coal slurry presently in operation in the United States is the Black Mesa pipeline from a mine in Arizona to the Mohave generating plant on the Colorado River, near Bullhead City, Nevada.

Several recent proposals have been made for coal slurry pipelines to transport coal from the Yellowstone Study Area to distant load centers. For example, Energy Transport Systems, Inc. (ETSI) has proposed a 38-inch pipeline with an annual capacity of 25 million tons of coal to be constructed from Gillette, Wyoming to White Bluff, Arkansas, a distance of over 1,000 miles. These proposals have raised a major issue over the "right of eminent domain". The proposed alignment of the Wyoming to Arkansas pipeline is reported to cross the tracks of nine railroads in 49 places (5). The railroads are reluctant to permit these crossings. The future of slurry pipe depends heavily on the enactment of Federal legislation granting the rights of eminent domain to slurry pipeline interests. Such legislation is currently under consideration. State policies, especially with respect to water rights, also will be of critical importance. It appears that the controversy could last for many years. Therefore, scenarios both with and without slurry pipeline development were considered.

Under the high regional energy development scenario, it was assumed that legal obstacles to slurry pipelines will be removed by 1985. However, it also was assumed that slurry pipelines will be constructed only in those situations when the rail line capacities of 40 million net tons in 1985 and 100 million net tons in the year 2000 are exceeded. A lower limit on slurry pipeline capacity of 10 million tons per year was considered the minimum flow needed for viable operation. Under the "most probable" and "low" scenarios, it was assumed that institutional, social, and environmental obstacles will preclude long distance coal slurry development.

Railroad Costs

Costs of shipping coal by unit train on a dollar per ton basis were determined from a composite of unit cost information given in a series of previous studies (6,7,8,9,10,11). The various estimates of shipping costs as compared to length of haul were plotted on graph paper. From these data

a composite curve was developed for use in preparing cost estimates for unit train shipments. These cost estimates were applied to the minimum path distance between the mining areas and the demand regions. In those demand regions with more than one load center, a weighted average cost was computed to represent the entire region. A summary of the costs of shipping coal by unit train over various distances is presented in Table B-4.

Table B-4

COSTS OF SHIPPING COAL BY UNIT TRAINS

Distance (Miles)	Unit Cost $ per Ton/Mile
0 to 750	$0.0114
750 to 1,250	0.0095
over 1,250	0.0086

The costs of shipping coal by conventional rail are substantially higher than by unit train. Since only one mode of transportation is available for industrial coal, the study results are not sensitive to the conventional rail versus unit train cost relationships. The costs of industrial coal transportation used in the model over any given line are approximately one-third more than the costs of the corresponding unit train operation.

Rail - Waterway Costs

Costs of shipment by the rail - waterway combination are determined by the sum of: (1) unit train costs to a transfer terminal, (2) transfer terminal costs, and (3) costs of waterway shipment to the final destination. As in the case of unit trains, unit costs of waterway shipments obtained from various sources were related to the length of haul, and cost estimates were derived from a composite curve. However, the capacity of the system is limited by the rail component in the vicinity of the mining areas. Furthermore, because of the distance between the study area and the waterways, no significant variation in the relative transportation economics of the mining areas results from the consideration of rail-waterway combinations. Therefore, inclusion or exclusion of the train-waterway transportation alternative in the model has no influence on the study results.

Transmission Line Costs

The costs of transmission lines and associated terminal facilities were estimated at 1975 price levels. The costs include land and right-of-way, civil works, purchase and erection of equipment, contractor's overhead and profit, engineering, and owner's administration.

The costs were estimated on the basis of recent Harza experience in the United States and secondary sources (14). Annual operation and maintenance costs for the lines were estimated at one percent of their construction cost. The construction cost based on 1975 dollars for 1,600 Megawatt transmission lines over various distances is presented in Table B-5.

Table B-5

CONSTRUCTION COSTS FOR 1,600 MEGAWATT TRANSMISSION LINES BY DISTANCE

Distance (Miles)	Total Construction Cost (Million Dollars)
480	354.2
680	447.9
880	541.6
1000	597.8

Coal Slurry Pipeline Costs

Slurry pipelines are competitive with alternative modes of coal transportation when very large tonnages are to be transported over medium to long haul lengths from a concentrated mining area to high capacity generating plants. A dispersion of mines in the supply area or of generating plants in the demand region adds greatly to costs. "For small operations, pipelines will seldom, if ever, be competitive with unit trains that have greater flexibility and can operate effectively for mines within a range of several hundred thousand to three million tons a year" (4).

All of the slurry pipelines recently proposed to transport coal from the Yellowstone Study Area are designed for annual capacities of 10 to 25 million tons. Several of the new mines in the study area are planned to produce 10 million tons or more of coal per year. Furthermore, the primary load centers in the demand regions for Yellowstone coal are at distances that tend to favor the slurry pipeline mode of transportation. Of course, the capacity of generating plants at the load center must be adequate to consume the large tonnages associated with pipeline operations.

As with any developing technology, there is a considerable uncertainty about the ultimate cost of coal transportation by slurry pipeline. The assumption was made under the high scenario that slurry pipeline transportation will be used only when railroad capacities are fully utilized. This assumption is reflected in the model by input of a unit cost of slurry pipeline transportation slightly higher than the unit cost of the corresponding unit train transportation.

The water requirement for slurry pipelines was taken as 600 Acre-feet per million tons of coal. This is equivalent to a proportion of about 45 percent water to 55 percent coal by weight in the slurry mixture.

APPENDIX C

CONVERSION ANALYSIS

This appendix summarizes the costs, resource requirements, and basic assumptions used in the linear programming (LP) model for coal conversion activities.

Coal Fired Generating Plants

Costs and Resource Requirements

A case study approach was used in estimating the costs of coal fired generating plants. Detailed information was assembled on several plants either planned or recently constructed at various locations in the Yellowstone Study Area and in the demand regions (References 26 through 36 in Bibliography). On the basis of this information, cost estimates were developed for a representative "base load" generating plant and key parameters were identified which significantly affect plant construction and operating costs. The costs of other types of plants were derived by making appropriate adjustments for variations in the key parameters. These parameters included water and coal availability, coal heating rate (BTU content), coal sulfur content, and type of plant cooling system.

The cost estimates for the representative "base load" generating plant were made in 1975 dollars on the basis of the following assumptions:

1. The plant is base loaded at 0.7 plant capacity factor.

2. Precipitators are provided to comply with environmental particulate matter emission limitations.

3. Allowable pollutant emissions of 1.2 pounds SO_2 per million BTU.

4. Plant capacity of 500 megawatts (MW).

5. Once through condenser cooling system.

The estimated costs and resource requirements for the base load plant and the changes that would occur with variations in plant design and key parameters are summarized in

Table C-1. These estimates are the basis of the inputs associated with thermal electric plant operation in the LP model.

The costs and resource requirements for a large variety of situations can be obtained from Table C-1 by adding combinations of features to the base load plant. For example, the construction cost of a plant to burn high sulfur coal with scrubbers would equal the cost of the base load plant of $324,000 per MW plus $70,200/MW for a total of $394,200/MW. If dry cooling were substituted for the once through condenser system assumed for the base load plant, this would add $34,000/MW to the construction cost. Corresponding changes would occur in the resource requirements and annual operating costs.

Water requirements are measured in acre-feet of consumptive use per year. The primary water losses are associated with condenser cooling system and scrubber evaporation. It was assumed that the cooling system blowdown was used for scrubber and other in-plant processes.

Remedial Options For High Sulfur Coal

Three alternatives were considered in burning high sulfur coal. These included the installation of scrubbers, blending with low sulfur coal at the plant site, and blending with low sulfur coal at the mine site. Costs and resource requirements for each alternative were estimated and are summarized in Table C-1.

Cooling Alternatives

The cooling methods investigated in addition to once through cooling include:

1. Cooling lake
2. Spray Pond
3. Mechanical Draft Wet Towers
4. Mechanical Draft Dry Towers
5. Natural Draft Wet Towers

Once through cooling systems involve the transfer of rejected heat from the thermal electric process to water which passes through the plant and then back to the natural

Table C-1

COSTS AND RESOURCE REQUIREMENTS PER MEGAWATT OF CAPACITY FOR COAL FIRED THERMAL ELECTRIC PLANTS

			Annual Resource Requirements			
Plant Type	Construction Cost ($)	Annual Operating Cost ($)[1]	Coal[2] (tons)	Water[3] (Acre-feet)	Land[4] (Acres)	Labor[5] (Man-Years)
Base Load Generating Plant (Per MW)	324,000	20,000	3,350	4.7	1.0	0.13
Design Variations on Base Load Plant		Incremental Costs and Resource Requirements				
Remedial Options for High Sulfur Coal						
Scrubbers	70,200	[6]	67	1.3	0.2	0.01
Plant Site Blending	3,500	[6]	3	[6]	[6]	[6]
Mine Mouth Blending	2,600	[6]	2	[6]	[6]	[6]
Cooling System Options						
Cooling Lake	3,500	[6]	7	9.1[7]	1.5	[6]
Spray Pond	6,400	[6]	36	10.6[7]	0.3	[6]
Mechanical Draft Wet Towers	4,000	[6]	27	10.6	[6]	[6]
Mechanical Draft Dry Towers	34,000	[6]	335	- 2.9	[6]	[6]
Natural Draft Wet Towers	8,500	[6]	21	[8]	[6]	[6]

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[1] Operating Costs do not include the costs of water, coal or transportation because these items are included as separate activities in the model.

[2] Based on coal with heating value of 10,000 Btu per lb.

[3] Consumptive use.

[4] Includes land for plant site only

[5] Operating personnel

[6] Requirements are not significantly different from base load plant. Variations that occur in the costs of water, coal, and transportation are reflected by other activities in the model as indicated by footnote No. 1.

[7] Average for study area based on wide range of estimates.

[8] Not estimated.

water body. These systems have been the most commonly accepted method of cooling in the United States to date. However, very limited use of once through cooling systems is anticipated for new plants in the future. Environmental regulations now impose limits on the water temperature increases in receiving waters.

Cooling lakes are commonly used to avoid thermal pollution associated with once through cooling. These lakes, which are usually man-made, hold the cooling water until the temperature declines to suitable levels for recirculation through the plant or discharge to natural water bodies. If the cooling lake is located where there is little or no natural drainage, or if the water rights belong solely to the utility company, then it is ordinarily considered to be under the complete control of the utility and not subject to thermal discharge regulations. However, any chemical discharges (blowdown) or other affects of the cooling lake on the environment are subject to State and Federal regulations.

Spray ponds are similar to cooling lakes, but mechanical devices are used to increase evaporative heat dissipation to the atmosphere. The consumptive use of water is generally higher than for cooling lakes, but less land area is required.

Cooling towers are usually either wet-type or dry-type with natural or mechanically induced draft. The mechanical draft wet towers cool the water by bringing it into contact with unsaturated air and allowing evaporation to occur. Heat is removed from the water as latent heat required to evaporate part of the water. Approximately 75 percent of the total heat transferred is by evaporation, the remainder by sensible heat transfer to the air (29, p. 349).

Mechanical draft dry towers rely upon conductive and convective heat transfer for their cooling effect. Air absorbs the heat from the cooling water which is circulated through the tower. The system is closed which allows for continuous reuse of water.

Mechanical draft towers are normally of treated wood or concrete construction, and they are available in round or rectangular configurations. The round tower is a relatively new configuration. It offers the advantages of requiring less space, minimizing recirculation requirements, and increasing performance.

Natural draft (hyperbolic) towers normally are constructed of concrete and require no fans. They utilize air

density differential between the atmosphere and the air inside the tower to generate required air flow. Natural draft towers are not considered practical for the study area. They require low wet bulb temperatures and high relative humidity for efficient operation. The climate of the study area is such that reliable continuous operation of natural draft towers is not likely.

The mechanical draft wet or dry towers were the options considered in the computer runs for this report. The LP model was designed to determine the cost of water at which dry cooling becomes economically preferable to the more water intensive wet cooling process. Although other methods of cooling are feasible under some conditions, the wet and dry tower alternatives are considered to yield an adequate estimate of resource demand for use in Level B planning.

Role of the PIES and LP Models

The PIES model determines the amount of electrical generation from coal mined in PIES Coal Supply Regions Nos. 7 and 8. It also indicates whether the generating plants are existing or new, medium (36 percent load factor) or base (70 percent load factor), and use low or high sulfur coal. The LP model determines, on the basis of the assumptions inherent in a particular scenario, whether the plants are likely to be located in the energy demand regions or in the mining areas, and whether they are anticipated to use wet or dry cooling towers.

Other Basic Assumptions

Plants in the energy demand regions and mining areas were assumed to have the same operational characteristics. The efficiency of the various types of plants is measured by the inverse of the heat rate. The heat rate values used in the LP model are the same as those used in the PIES model, except for plants with dry cooling towers where the heat rate is ten percent higher than for plants with wet cooling towers. These values are summarized in Table C-2. The influence of differing Btu content for coal is handled endogenously by appropriate activities in the LP model.

The trade-off between the alternatives of (1) burning low sulfur coal, or (2) burning high sulfur coal with an appropriate desulfurization technique is evaluated by the PIES model. Under the Reference Case (see Chapter II) selected for this analysis, environmental standards are met by burning either acceptable low sulfur coal or high sulfur coal with scrubbers.

Table C-2

HEAT RATE VALUES FOR VARIOUS TYPES OF PLANTS

Plant Type				Heat Rate (Btu/Kwh)
Age	Load Factor	Sulfur Content of Coal	Cooling Method	
New	Medium	Low	Dry	11,000
"	"	Low	Wet	10,000
"	"	High	Dry	11,600
"	"	High	Wet	10,500
"	Base	Low	Dry	10,100
"	"	Low	Wet	9,200
"	"	High	Dry	10,600
"	"	High	Wet	9,600
Existing	Medium	Low	Wet	10,600
"	"	High	Wet	10,600
"	Base	Low	Wet	9,800
"	"	High	Wet	9,800

The operating costs and capital, water, land and labor requirements from Table C-1 were converted to resource units per gigawatt hour (Gwh) for input to the LP model. A base load plant generates 6.132 Gwh/year/MW and a medium load plant generates 3.154 Gwh/year/MW.

It should be noted that annual operating costs do not include the costs of coal, water, or transportation because they are included as separate activities in the model. For existing plants, the construction cost is considered sunk so a return on capital is not included in the total cost of the activity in the objective function. For new plants, an annual allowance for return on capital equal to 12 percent of the construction cost is added to the operating costs.

Constraints were provided in the model to ensure that the capacity of plants already existing or under construction will be fully utilized and that any additional capacity required would be considered as new. The plants included as existing generation are:

Mining Area	Name	Capacity (MW)
1	Leland Olds	678
	Beulah	14
	R. M. Heskett	100
	Milton R. Young #1	256
	Stanton	172
		1,220
2	Lewis and Clark	50
3	--	0
4	Colstrip #1	330
	Colstrip #2	330
	Frank Bird	69
	J.E. Corette	171
		900
5	Osage	35
	Neil Simpson	25
	Wyodak	330
		390
6	--	0

Capacities of less than 10 MW were not considered.

Coal Gasification Plants

Announced Plans

Plans have been announced for the construction of six high-BTU coal gasification projects in the United States. Four of these projects are located in the Yellowstone Study Area. A list of the announced gasification plants is presented in Table C-3. One of the plants is located in Eastern Wyoming, two are located in North Dakota, and one is located in the Powder River Basin in Wyoming.

The typical announced plant unit would produce 250 million cubic feet per day (MCFD) of pipeline quality synthetic natural gas. All of the projects would use the Lurgi pressure gasification process plus shift conversion, purification, and methanation technologies to produce high-Btu gas. The synthetic gas has a methane content of about 95 percent and combustion heat of about 960 Btu per standard cubic foot (SCF) on a dry basis.

The Lurgi process is a proven technology which was developed in Germany over fifty years ago. Lurgi units producing low Btu gas operate commercially in South Africa and Scotland. The methanation process to produce high Btu or pipeline quality gas has been demonstrated in pilot plants, but its viability has not been demonstrated in commercial operation.

Cost of Synthetic Gas Production

Current estimates place the construction cost of a high Btu gasification plant, including the mine, with a capacity of 250 MCFD at about $1.3 billion. This implies a cost of production of about $3.50 to $4.00 per thousand cubic feet (MCF), based on 1975 dollars and financing at 9 percent interest. In addition, costs will be incurred in transmitting the gas to consuming areas. These transport costs will vary depending on the proximity of the plants to natural gas pipelines and the consuming areas.

Price Outlook

The Project Independence Evaluation System (PIES) model forecasts a market clearing city gate price for natural gas in 1985 of $2.03 per MCF. This forecast is based on an uncontrolled market or deregulated condition and $13 per

Table C-3

ANNOUNCED COMMERCIAL HIGH BTU COAL GASIFICATION PLANTS[1]

Company	Site	Plant Output MCFD[2]
El Paso Natural Gas Company	Four Corners Area, New Mexico	288
WESCO	Four Corners Area, New Mexico	1,000 (4 Units)
Panhandle Eastern Pipeline Co.	Eastern Wyoming	270
Natural Gas Pipeline Co. of America	Dunn County, North Dakota	1,000 (4 units)
American Natural Gas Co.	Beulah-Hazen Area, North Dakota	1,000 (4 units)
Northern Natural Gas Co. and Cities Service Co.	Powder River Basin, Montana	1,000 (4 units)
	TOTAL	4,558

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[1] Source -- Institute of Gas Technology (46, p. 21)

[2] Million cubic feet per day

barrel world oil prices. This price for natural gas is substantially below the cost of production and transport for synthetic natural gas.

Uncertainty regarding the future price of world oil is regarded as one of the major reasons that none of the announced coal gasification projects have proceeded to construction. The PIES model indicates that a price equivalent of $19 per barrel of oil would be required for coal gasification projects to receive an acceptable return on investment (2, p. 156). Other important risks include:

1. Uncertainty about air and water quality standards;
2. Coal availability as constrained by leasing rates and environmental concerns;
3. Water availability;
4. Federal regulation of price of fuels;
5. Availability of labor, materials, and equipment;
6. Need for development of additional environmental control technology;
7. Extent of socioeconomic impact,
8. Unforeseen project delays.

Coal Gasification Forecast

The PIES model and other estimates developed for this study indicate that the cost of producing synthetic natural gas will likely exceed the cost of energy from other sources through the year 1990. Therefore, no coal gasification activity is forecast for the Yellowstone Study Area on the basis of purely economic criteria. However, FEA assumes in the 1985 Reference case that financial incentives will be provided for synthetic fuel development of 880 million barrels per day oil equivalent. This incentive program is expected to result in the construction of one coal gasification plant in the Yellowstone Study Area by 1985 under both the high and most probable regional energy development scenarios. No coal gasification activity is anticipated under the low forecast.

Beyond 1990, the financial incentives program coupled with dwindling domestic reserves of natural gas and oil are expected to result in a rapid expansion of coal gasification

activity. This view is supported by other long range forecasts such as the Stanford Research Institute (SRI) model (6), Bureau of Mines (15), and Manne (20). For example, under the SRI nominal case, 45 coal gasification plants are forecast for location in the North Dakota, Montana, and Wyoming area by the year 2000. The Bureau of Mines forecast indicates the national output of coal gasification plants is expected to grow from 380 billion cubic feet in 1985 to 4,670 billion cubic feet in the year 2000-over a twelve fold increase (15, p. 42). This would represent approximately five coal gasification units in the United States by 1985 and 57 units by the year 2000, based on an average unit capacity of 250 MCFD.

On the basis of analyses conducted with the Harza linear programming model, it appears that resource availability, environmental concerns, and social preferences, rather than economic demand, will act as the primary constraints on coal gasification development in the Yellowstone Study Area in the year 2000. By the year 1990, a large number of coal mines and thermal electric plants will already have been developed in the study area. Although coal reserves will remain relatively plentiful, it is anticipated that the number of coal gasification plants will be limited by the diminishing supplies of other resources, such as water, and the social, environmental, and institutional problems associated with energy development. A summary of projected high Btu coal gasification plants in the Yellowstone Study Area for the year 2000 under the three regional energy development scenarios is presented in Table C-4.

The high regional energy development scenario was determined by an analysis of industry expansion plans and by consideration of those constraints imposed by resources availability. The most probable scenario reflects a lower rate of development resulting from assumed more stringent environmental, social, and institutional constraints. The low forecast assumes no coal gasification development.

Resource Requirements

The estimated costs and resource requirements for a representative 250 million cubic feet per day (MCFD) capacity coal gasification plant are summarized in Table C-5.

Estimated construction costs are based on recent information published by ERDA (45). Costs are in 1975 dollars and

Table C-4

PROJECTED HIGH BTU COAL GASIFICATION PLANTS IN THE YELLOWSTONE STUDY AREA BY THE YEAR 2000

Company	Site	Forecast				
			Most Probable		High	
		Low	No. of Units	Capacity (MCFD)	No. of Units	Capacity (MCFD)
Panhandle Eastern	E. Wyoming	0	2	540	4	1,080
Natural Gas Pipeline	Dunn County, North Dakota	0	3	750	4	1,000
American Natural	Beulah-Hazen, North Dakota	0	3	774	3	774
Northern Natural-Cities Svc.	Powder Riv. Basin, Montana	0	3	750	4	1,000
Colorado Interstate Gas, Co.	S. E. Montana	0	1	250	2	500
Exxon Corporation (Carter Oil)	N. Wyoming	0	1	120 1/	1	120 1/
El Paso Natural Gas	S. W. North Dakota	0	2	500	3	750
TOTAL		0	15	3,684	21	5,224

1/ In addition, Exxon to produce undetermined liquid and gas. Assumed syncrude and gas. Product would approximate 42,500 BPD of "crude" at 5.8 million Btu per barrel.

Table C-5

COSTS AND RESOURCE REQUIREMENTS FOR 250 MCFD COAL GASIFICATION PLANT

Item	Unit	Amount
Construction Cost[1]	Million Dollars	1,000
Resource Requirements		
Coal[2]	Million Tons/year	10
Water[3]		
Normal Usage	Acre Feet/Year	10,000
Partially Air-Cooled	Acre Feet/Year	6,000
Land[4]	Acres	500
Labor[5]	Man-year Equiv./Yr	625

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[1] Excludes the cost of associated mine.

[2] Based on coal with heating value of 13 million Btu per ton.

[3] Consumptive use.

[4] Includes land for plant site only. Strip mined area is included under mining activities.

[5] Plant operating personnel only.

do not include the cost of the associated mine because mining is a separate activity in the LP model.

Coal requirements are reported in million tons per year based on a heating value of 13 million Btu per ton. Differences in heating value are accounted for by conversion coefficients in the LP model.

Water requirements for coal gasification vary depending upon process design, composition of the feedstock, climate, type of cooling, water quality, and other such considerations. Water is used for both process purposes and cooling. In processing, water is used to generate steam and supply hydrogen for the reaction. The consumptive use of water for a representative 250 MCFD plant using the Lurgi Process is estimated at 10,000 acre feet per year under normal usage and 6,000 acre feet with partial air cooling. This includes all water uses at the plant site. It does not include mining and reclamation water requirements which are considered elsewhere.

The land requirements are for the plant site only. Annual labor requirements are in man-year equivalents for plant operating personnel only.

APPENDIX D

AIR AND WATER QUALITY CONSIDERATIONS

The preparation of an environmental impact statement on energy development in the Yellowstone Study Area was beyond the scope of the Harza contract. However, it was necessary to consider the air and water quality implications of coal mining and conversion activities in order to adequately forecast the pattern of energy development. A basic assumption in the analysis is that current environmental standards will prevail and any development must occur within the associated constraints.

This appendix identifies the known air and water pollutant emissions associated with coal mining and conversion activities and presents output coefficients for those that can be realistically measured by the study model. Numerical estimates are provided by the linear programming model of air emissions including particulates, sulfur oxides (SO_x), and nitrogen oxides (NO_x). Other emissions are considered qualitatively. A summary of these anticipated emissions is presented in Chapter III under the section entitled "Results of the Micro Analysis."

Coal Mining

Water Quality

Strip mining activities can lead to water quality degradation of both surface and ground water supplies unless adequate steps are taken to prevent such changes. Poor spoil pile disposition and steep slopes lead to the introduction of large silt loads to tributary streams draining the strip mining operation. If no land reclamation processes are implemented, erosion of the piles will continue to add silt loads to the streams for decades after the operation has ceased. The effects of increased silt loading to the streams could be felt for long distances downstream of the operation. Concomitant with the silt introduction is the increase of total dissolved solids (TDS) in the stream.

The strip mine operation breaks up and fragments the rock strata and soil layers so that as water percolates

down, it takes up many times more chemical elements than it would from an undisturbed area. The Northern Great Plains Resources Program (NGPRP) report cites the following data (Table D-1) from Van Voast (1973) on water samples from two wells in the Colstrip area of Montana (1, p. 98). One well taps old spoil materials and the underlying Rosebud coalbed; the other taps an unmined coal bed.

Table D-1

WATER QUALITY OF TWO WELLS IN MINED AND UNMINED AREAS

(Parameters are in milligrams per liter)

	Water from old spoils and the Rosebud coalbed	Water from the unmined coalbed
Date of collection	9-25-73	9-25-73
Calcium (Ca)	467	53
Magnesium (Mg)	351	51
Sodium (Na)	114	190
Potassium (K)	9.0	8.1
Iron (Fe)	1.82	0.26
Manganese (Mn)	1.25	0.07
Silica (SiO_2)	16.0	14.3
Bicarbonate (HCO_3)	483	553
Carbonate (CO_3)	0	0
Hydroxide (OH)	0	0
Chloride (Cl)	15.9	4.1
Sulfate (SO_4)	2,418	284
Nitrate (NO_3)	15.5	1.1
Fluoride (F)	0.1	0.1
Calculated dissolved solids	3,892	1,159

Contaminated ground-water can enter a stream or river and thus pollute the surface water of the area.

The chemical composition of the coalbed, the overlying rock strata and the soil types all greatly influence the type and extent of groundwater and surface water contamination. In areas where the coal contains little pyrite and

highly alkaline soils overlie the site, the water will become very alkaline. The Rocky Mountain Coal Province, including the upper reaches of the Yellowstone and the Bighorn Rivers, has such a composition and would probably exhibit such water quality changes, (37, pp. 3-20). In other areas, coal deposits are higher in sulfur (pyrite) content and will produce the more common acid-mine type of pollution associated with coal strip mining, with very low pH values in the groundwater and streams.

The washing and refining of the coal can add more pollutants to the streams unless the effluent is properly treated prior to discharge. Once again the final change in water quality would be based on sulfur content and the presence and amount of other impurities in the coal.

Air Quality

Air quality will be influenced by two aspects of strip mine operation. First, the operation of the mine could introduce sizable amounts of coal dust and dirt from the quarrying process; secondly, earth moving equipment will produce diesel exhaust gases at the sites.

Coal refuse fires, though not of common occurrence, produce serious air pollution because of the high concentrations of sulfur oxides.

Coal Fired Generating Plants

Water Quality

A number of areas of environmental concern have been linked to steam power plant discharges. The production of large quantities of waste heat by the plant will require the use of large volumes of water which will be released, either periodically or at a constant rate, into receiving waterways. Such thermal discharges result in both primary and secondary impacts to the aquatic systems. Direct thermal effects on fish and the decrease of dissolved oxygen levels as temperatures increase are examples of primary impacts, and increased toxic effects of chemicals such as chlorine illustrate secondary impacts.

Due to water consumption by power plants via water evaporation in cooling towers, the levels of chemical constituents in the intake water are greatly increased by the time

the water is returned to the stream or river. This concentration of chemical constituents has been estimated for total dissolved solids (TDS) to be 3.8 times that of the intake water levels (1, p. 93). This estimate, from the NGPRP report, was based on an assumed annual water intake of 19,000 acre-feet with an annual discharge of 5,000 acre-feet for a 1,000 megawatt size powerplant.

Stratton and Lee (38) have studied the water quality of the make-up and blowdown waters from eleven cooling towers and found that ammonia, nitrate, phosphorus, sulfate, zinc, iron, copper, chromium, lead and mercury levels were significantly increased in the blowdown waters. The authors credit the increases to concentration by evaporative water loss in the towers, corrosive processes in the towers (e.g., zinc and iron), addition of biocides (phosphorus and sulfate) to control undesirable organisms, and stripping from the atmosphere (ammonia, nitrate and sulfate).

Chlorine is often added to powerplant intake water to control fouling organisms in the cooling towers and plant water distribution systems. Although the U.S. Environmental Protection Agency standard for free available chlorine is 0.5 milligrams/liter, recent studies suggest that this level is not entirely adequate to protect aquatic life (39).

Ash piles can act as serious pollution sources for ground water and surface water unless the site is suitable for containing the ash and preventing leaching of elements to the water table. As the combustion of coal acts to concentrate the non-volatile portion of the coal, most of the same elements found in the coal will be found in the ash but in much higher concentrations.

Air Quality

Coal-fired steam electric power plants produce air emissions which are high in particulates, sulfur oxides (usually SO_2, but also others; these are often shown as SO_x) and nitrogen oxides (NO_x). For the purpose of computing the pollutant emission levels corresponding to the electric generation forecast in the study area, the following coefficients were used: particulate emissions, 0.5 tons per Gigawatt-hour (Gwh); SO_x emissions, 6 tons/Gwh; NO_x, 5 tons/Gwh. In addition, stack emissions contain unknown concentrations of trace elements. These elements include aluminum, antimony, arsenic, beryllium, boron, calcium, cadmium, fluorine, iron, lead, magnesium, manganese, mercury,

nickel, potassium, selenium, sodium, titanium, vanadium, and zinc. A portion of these elements may be volatized and leave the stack in this form rather than in particulate form. The quantity of these elements in the air emissions depends on their quantity in the coal ore but no precise mass-balance studies have been done to date to show definitive relationships. One important note is that the concentration of sulfur dioxide (SO_2) in the stack gases increases in relation to an increase in aluminum and silicon in the coal and SO_2 decreases with increased levels of calcium and sodium oxides (1, p. 29). Radioactive elements are found in the coal from the Rocky Mountain Coal Province and are concentrated in the ash (37). Some portion probably is released in the stack emission but this has not been confirmed and is expected to be extremely low.

Coal Gasification Plants

The identification of air and water pollutants from coal gasification is dependent on several important variables. A number of different processes can be used to produce synthetic gas from coal (e.g. Synthane Process, Koppers Totzen Process, Hygas Process, Lurgi Process, Winkler Process). Each process results in a different array of gaseous by-products which have a potential of being released to the atmosphere or dissolved in waste water from the facility (40, 41, 42, 43). The process products also can change significantly according to the chemical composition of the coal source.

Water Quality

The principal source of potential water quality degradation occurs during the scrubbing operation where H_2S, ammonia, cyanide, thiocyanide, phenols, chlorides, and sulfur oxides are transferred from hot raw gas to cooling water via direct contact (43). Arsenic, cadmium, lead, chlorine, fluorine and other trace elements may also be present in this "gas liquor". The treatment of this effluent usually calls for chemical, biological, and physical processes before it is recycled in the plant boilers or discharged.

Because of the early stage of development of this type of facility, little data exist on the effect of plant discharges on water quality. As these facilities will be

similar to existing powerplants in that they will use cooling towers to dissipate waste heat, the discussion of water quality in relation to steam electric plants will also generally apply to coal gasification plants. It should be noted that concentration of water quality chemical constituents will be somewhat less than for powerplants. The NGPRP report indicates that total dissolved solids will be concentrated by factor of 1.5 to 3.0 (1, p. 93).

Processes are available whereby water used in various parts of the gasification process can be clarified and recycled within the plant to minimize water withdrawal. Utilization of a closed water system using water reclamation processes also decreases the effect of water discharges to receiving streams as this return flow is minimized. In some planned facilities, there is no water returned to surface waters. Water not amenable to further reuse can be disposed of via the use of evaporation ponds or deep-well injection techniques. A plant having such a closed system will have its main effect in reduction of water flow rather than water quality.

Air Quality

During the gasification process, many of the gaseous by-products are shunted from one stage to another to improve reaction conditions. Some process by-products are removed from the cycle and recovered in a marketable form. Such by-products include sulfur, naphtha, anhydrous ammonia and crude phenol. Those chemical compounds which cannot be economically recovered are removed from the system and incinerated. If the processes and plant facilities operate as planned, emission products will be CO_2, N_2, H_2 and water vapor. In actuality, some additional gaseous pollutants, such as methane, ethane, H_2S, SO_2, NO_x and COS (Carbonyl sulfide) may enter the atmosphere as a result of imperfect system design, inefficiencies in the facilities, or plant shut-down. While the significance of such emissions is not presently known, their potential should be considered during the planning process.

A representative plant with 250 MCFD capacity and 500 foot stack has been estimated to produce about 2,800 pounds per hour of SO_2, 1,870 pounds per hour of NO_x and 255 pounds per hour of particulate material (44).

Appendix E

DESCRIPTION OF THE LINEAR PROGRAMMING MODEL

This appendix consists of a schematic diagram of the LP matrix, a guide to the computer output, a complete print-out of the 2000 Most Probable scenario, and summary tables corresponding to the other scenarios. Detailed information about specific activities of the model is presented in the relevant Appendices.

Diagram of the LP Matrix

A general description of the activities and constraints included in the LP matrix is found in Chapter III. A schematic diagram of the matrix is presented in Exhibit E-1. The various categories of activities and constraints are shown along with the corresponding non-zero coefficients. The legend indicates the physical interpretation of these coefficients.

EXHIBIT E-1

ACTIVITIES	MINING ACTIVITIES BY AREA				COAL TRANSPORTATION BY ORIGIN AND DESTINATION				BTU CONVERSION IN MINING AREA		CONVERSION TO ELECTRICITY IN MINING AREA BY AREA AND COOLING METHOD						CONVERSION TO ELECTRICITY IN UTILITY REGION BY REGION						CONVERT TO SNG IN MINING AREA		TRANSMIT ENERGY	CONSTRAINT	VALUE
	EXISTING		NEW		UTILITY		INDUSTRIAL				EXISTING		NEW				EXISTING		NEW						BY ORIGIN AND DESTINATION		
CONSTRAINTS			LS	HS	TRANSPORTATION MODE		REG. RAIL						DRY		WET				DRY		WET		BY AREA				
	LS	HS	HO LO	HO LO	LS	HS	LS	HS	LS	HS	LS	HS	LS	HS	LS	HS	LS	HS	LS	HS	LS	HS	LS	HS	MODE		
RESOURCE REQUIREMENTS																											
WATER	+				+						+						+						+		+	U	
LAND																										U	
LABOR																										U	
CAPITAL																										U	
OBJECTIVE																											
TOTAL COST	+				+						+						+						+		+	U	
MATERIAL BALANCE																											
MINING LS	−1		−1						1/A																	=	0
MINING HS		−1		−1						1/A																=	0
CONVERSION TO ELECTRICITY IN UTILITY REGION LS					−1												+H		+H		+H					=	0
CONVERSION TO ELECTRICITY IN UTILITY REGION HS						−1												+H		+H		+H				=	0
LOCAL CONVERSION AND TRANSPORTATION LS					+		+1		−1		+H		+H		+H								+A			=	0
LOCAL CONVERSION AND TRANSPORTATION HS						+1		+1		−1		+H		+H		+H								+A		=	0
TRANSMISSION											−1		−1		−1											=	0
DEMAND																											
COAL-FIRED ELECTRICITY IN UTILITY REGION																	+1		+1		+1				+1	=	D_E
INDUSTRIAL COAL IN DEMAND REGION							+1	+1																		=	D_I
PRODUCTION CAPABILITIES									←		I						→									≤	PC
OTHER CONSTRAINTS	+				+																		+			≤	L

LEGEND

ROWS

D_E : DEMAND FOR ELECTRICITY
D_I : DEMAND FOR INDUSTRIAL COAL
PC : PRODUCTION CAPACITY
U : UNCONSTRAINED
L : LIMIT

COLUMNS

LS : LOW-SULFUR COAL
HS : HIGH-SULFUR COAL
LO : LOW OVERBURDEN RATIO
HO : HIGH OVERBURDEN RATIO

COEFFICIENTS

A : BTU CONTENT OF COAL
H : UTILITY HEAT RATE
I : IDENTITY MATRIX
K : ENERGY TRANSMISSION EFFICIENCY
+ : POSITIVE COEFFICIENT
1 : COEFFICIENTS ARE ONE

HARZA ENGINEERING COMPANY · DECEMBER 1976

COAL SUPPLY MODEL
YELLOWSTONE ENERGY STUDY

Guide to the Computer Output From the LP Model

The computer output generated by a run of the model includes the following information:

I. Control Program. Sequence of calls to various subroutines of the FMPS package; it controls the execution of the run.

II. Input Data. The non-zero coefficients of the LP Matrix are listed by rows.

III. Solution. The print-out is divided into two sections:

A. Columns of the LP matrix, corresponding to the activities of the model.

For each column, the following information is provided: Name of activity, status, level of activity, input cost, lower limit, upper limit, reduced cost. The abbreviations for the "status" of the column are as follows:

LL	indicates that the variable is at its lower limits (usually zero).
UL	indicates that the variable is at its upper limit.
BS	indicates that the variable is between its lower and upper limits. (basic variable).
EQ	indicates that the variable is at a fixed level (lower limit = upper limit).

The reduced cost is the dual variable associated with the limits on the activity.

B. Rows of the LP matrix, corresponding to the constraints on the activities.

For each row, the following information is provided: Name, status (same abbreviations as for the column section), activity, slack activity, lower limit, upper limit and dual activity. The dual activity represents the decrease in total cost that would

be obtained if an additional unit of capacity was available.

IV. Summary Table. The mining and processing activities in each mining area are tabulated along with the corresponding resource requirements.

Code List

I. Column Section

Two types of activities are included in the model: (1) fundamental activities and (2) aggregate activities. The aggregate activities are linear combinations of the fundamental activities and are included in the model for the purpose of computing the resource requirements.

A. Mining Activities

1. Fundamental activities

1st character: M = mining

2nd character: mining area number

3rd character: age of mine

E = existing
N = new

4th character: type of coal

L = low sulfur
H = high-sulfur

5th character: 1 for all mining activities

6th character: overburden ratio

1 = low
2 = medium
3 = high

(see Table A-2 for numerical values)

Example. M1NL12 means: mining in area 1 (North Dakota Lignite) in a new mine, low-sulfur coal, medium overburden ratio.

2. Aggregate Activities.

Mn : Total coal production of mining area n.

LMMn: Labor requirement in mining area n.

RMMn: Return on capital requirement for new mines in mining area n.

SMMn: Strip-mined land in mining area n.

WPMn: Water use for slurry pipes in mining area n.

B. Conversion to BTU's

These activities are linear combinations of the mining activities and convert million tons of coal to trillion (10^{12}) BTU's.

They are designated as:

BCMnL or BCMnH

which stands for: BTU conversion in mining area n, low or high-sulfur coal.

C. Transportation Activities

1st character : T for transportation

2nd character : number of the mining area where the link originates, as follows:

1. North Dakota Lignite
2. Eastern Montana Lignite
3. Montana Powder River Lignite
4. Montana Powder River Subbituminous

5. Wyoming Powder River Lignite

6. Wyoming Powder River Subbituminous

3rd character : type of destination

D = "demand" region (industrial coal)
U = "utility" region (utility coal)

4th and possibly 5th character: number of the region where the link terminates (see Exhibit 1, page II-2 of report), as follows:

4. East North Central

5. East South Central

6K. Kansas City

6L. St Louis

6M. Minneapolis-St. Paul

7. West South Central

8. Mountain

One character : type of coal

L = low-sulfur
H = high-sulfur

One character : mode of transportation

R = "regular" rail (shipments too small to justify the use of unit trains)

U = unit train

S = slurry pipeline

Examples:

T1D6MHR means transportation from mining area 1 (North Dakota Lignite) to demand region (industrial coal) 6M (Minneapolis-St. Paul) of high-sulfur coal by regular rail.

T6U7LS means transportation from mining area 6 (Wyoming Powder River Subbituminous) to utility region 7 (West South Central) of low-sulfur coal by slurry pipeline.

D. Conversion to Electricity in Mining Areas

1. Fundamental Activities

First character : C = conversion

Second character: M = mining area

Third character : n = mining area number

Fourth character:

N = new plant
E = existing plant

Fifth character : load factor

M = medium load
B = base load

Sixth character : type of coal burned

L = low sulfur
H = high sulfur

Seventh character: type of cooling

D = dry cooling
W = wet cooling

(for existing plants, this character is 0 since there is no option on the cooling system)

Example:

CM4NBLW means: thermal-electric generation in mining area 4, new plant, base load, low-sulfur coal, wet cooling.

2. Aggregate Activities

CMnC : coal consumption for electricity generation in mining area n.

RCMn : return on capital for new thermal-electric plants in mining area n.

E. Synthetic Gas Activities

1. Fundamental Activities

SGASMnL : amount of coal used for conversion to synthetic gas in mining area n, low-sulfur (L) or high-sulfur (H).

2. Aggregate Activities

SYNGASMn = SGASMnL + SGASMnH

total amount of coal (low and high-sulfur) used for conversion to synthetic gas in mining area n.

F. Conversion to Electricity in Utility Region

1. Fundamental Activities

First character: C = conversion

Second character: U = utility region

Next one or two characters: utility region code as follows:

4. East North Central

5. East South Central

6K. Kansas City [1/]

6L. St. Louis[1/]

6M. Minneapolis-St. Paul[1/]

7. West South Central

8. Mountain

Last four character: same as for conversion in mining areas.

[1/] West North Central

2. Aggregate Activities

No aggregate activity is included in the model because conversion in utility regions does not use any study area resources other than coal.

G. Electricity Transmission Activities

First character : L = transmission line

Second character: n = number of the mining area where the transmission line orginates.

Third character : U = utility region

Next one or two characters: number of utility region where transmission line terminates (see above).

The remaining characters describe the type of plant and the type of coal used in the generation of electricity (this breakdown is necessary for the interface with the PIES model).

One character : age of plant

N = new
E = existing

One character : load factor

B = base load
M = medium load

One character : type of coal

L = low-sulfur
H = high-sulfur

Examples:

L1U6KEBL means transmission to utility region 6K (Kansas City) of electricity generated in mining area 1 (North Dakota Lignite) in an existing, base load plant burning low-sulfur coal.

L4U8NMH means transmission to utility region 8 (Mountain Region) of electricity generated in mining area 4 (Montana Powder River Subbituminous) in a new, medium load plant burning high sulfur coal.

II. Row Section

The rows are a set of linear equalities and inequalities which ensure the consistency of the model, enforce the various constraints, and define the economic demands for industrial and utility coal.

The right-hand side of these equations and inequalities is contained in the column labelled "RHS". In the performance of the parametric analysis, the values of the components of the change vector are contained in column "CHANGE".

A list of the codes for labelling the rows is provided below:

Row 1: LABCOST = labor requirement, in man-year equivalent/year.

Row 2: OPECOST = operating cost for thermal-electric power plants.

Row 3: WATCOST = water consumption in study area (excluding water reclamation).

Row 4: CAPRET = return on capital for new investments in the study area.

Row 5 : RECFEE = water consumptive use for land reclamation.

Row 6 : STRILAND = strip-mined land.

Row 7 : LANDUSE = land used for sites of mines and power plants.

Row 8 : TOTCOST = objective function. Total cost of energy production.

Rows 9 through 56: these rows are the equalities defining the aggregate activities. The first letter of the code name is an A.

AMn : Computation of coal production in mining area n by summing the various mining activities in the area.

ALMMn : computation of the labor requirement associated with mining in area n.

ARMMn : computation of capital return associated with new mines in area n.

ASSMn : computation of strip-mined land in area n.

AWPMn : computation of the water requirement for slurry pipe activity in mining area n.

ACMnC : computation of coal consumption by thermal-electric plants in mining area n.

AWCMn : computation of water consumptive use by thermal-electric plants in mining area n.

ARCMn : computation of capital return associated with new thermal-electric plants in mining area n.

Rows 57 through 176: These rows represent the material balance equations, which ensure the consistency of the model. The first two letters of the code name are MB (Material Balance).

The last digit represents the type of material balance equation:

"1" for the rows labelled "Mining on Exhibit E-1. These rows link the mining activities, in million tons/year, to the corresponding Btu conversion activities, which enable the model to account for the various coal Btu contents.

"2" for the rows labelled "local conversion and transportation" on Exhibit E-1.

These equations state that all the coal mined in one area is either shipped to an energy demand area by some transportation mode or burned in a thermal-electric plant in the mining area.

"3" for the rows labelled "Transmission" on Exhibit E-1.

These equations state that all the electricity generated in any mining area is transmitted, with a certain loss, to an energy demand region.

"4" for the rows labelled "conversion to electricity in utility region" on Exhibit E-1.

These equations state that in any energy demand region all the coal shipped by unit train or slurry pipeline is burned in a thermal-electric power plant.

The coding of these rows is as follows:

A. Mining

First two characters: MB = material balance

Third character: M = mining

Fourth character: n = mining area number

Fifth character: type of coal

L = low-sulfur
H = high-sulfur

Sixth character: for mining areas 1 through 6, equation type.

1 = mining

for mining areas 8 and 9, type of mine

1 = strip-mine
2 = deep mine

The seventh character represents the equation type:

1 = mining

B. Local Conversion and Transportation

First two characters: MB = material balance

Third character: B = Btu conversion

Fourth character: M = mining area

Fifth character: n = mining area number

Sixth character:

L = low-sulfur
H = high-sulfur

Seventh character: type of equation

2 = Local conversion and transportation

C. Transmission

First two characters: MB = material balance

Third character: L = transmission line

Fourth character: n = mining area number

Fifth Character: age of plant

E = existing
N = new

Sixth character: load factor

M = medium
B = base

Seventh character: type of coal

L = low-sulfur
H = high-sulfur

Eighth character: type of equation

3 = transmission

D. Conversion to Electricity in Utility Region

First two characters: MB = material balance

Third Character: E = Electricity

Fourth Character: U = Utility Region

One or two characters: utility region number, n or nX (see conversion activities)

One character: type of coal

L = low-sulfur
H = high-sulfur

One character: type of equation

4 = conversion to electricity in utility region.

Rows 177 through 183: RAILCAP2 through RAILCAP8

These rows correspond to the railroad line capacity constraints. The last digit corresponds to the railroad line number (a table in Appendix B shows which transportation links use a given line).

Rows 184 through 189: CMnEX, n mining area number. These constraints force the model to use the existing capacity fully in each mining area.

Rows 190 through 207: CMnPAR, CMnSO2, CMnNO_x. These rows determine the amount of particulates, SO_x and NO_x respectively emitted by the thermal-electric power plants in mining area n.

Rows 208 through 263: demands for electricity in the utility regions.

First three characters: DEU = demand for electricity in utility region.

One or two characters: utility region number (see conversion activities).

One character: age of plant

N = new
E = existing

One character: load factor

M = medium
B = base

One character: type of coal

L = low-sulfur
H = high-sulfur

Rows 264 through 277: demand for industrial coal in energy demand regions.

First four characters: DICD = demand for industrial coal in energy demand regions.

One or two characters: demand region number (see conversion activities).

One character : type of coal

L = low-sulfur
H = high-sulfur

III. Units

A. Columns

Mining activities	million tons/year
Labor requirement	man-year eq./year
Return on capital	million $/year
Strip-mined land	acres/year
Water use	acre-feet/year
Conversion to Btu	trillion (10^{12}) BTU/year
Transportation Activities	trillion BTU/year
Conversion to electricity	Gigawatt-hours/year
Synthetic gas activities: coal consumption	million tons/year
Electrical transmission	Gwh/year (1 Gigawatt-hour = 10^6 kilowatt-hours)

For the activities in trillion Btu units, the corresponding amount of coal in million tons/year is obtained by dividing the activities by the Btu content of the coal, as follows:

Mining Area	1	2	3	4	5	6
BTU content (10^6 BTU/ton)	13.74	13.4	14.2	17.39	16.45	18.9

B. Rows

LABCOST	man-year equivalent/year
OPECOST	million dollars/year
WATCOST	acre-feet/year
CAPRET	million dollars/year
RECFEE	acre-feet/year
STRILAND	acres/year
LANDUSE	acres
TOTCOST	million dollars/year
RAILCAPn	million tons of coal/year
CMnEX	megawatts capacity
CMnPAR	tons of particulates/year
CMnSO2	tons of SO_x/year
CMnNOX	tons of NO_x/year
DEU's	Gwh/year
DICD's	trillion (10^{12}) BTU/year

C. Matrix Coefficients

The unit of a coefficient of the Matrix is the ratio of the unit of the corresponding row divided by the unit of the corresponding column.

This guide is intended only to provide the information necessary to the understanding of the computer output. The reader is referred to the relevant chapters and technical appendices of the report for a discussion of the assumptions and data used in the model. Specific information about the computer program used to solve the LP model can be found in the Functional Mathematical Programming System (FMPS) User's Manual (66 in Bibliography).

SUMMARY TABLES

SUMMARY TABLE

RESOURCE REQUIREMENTS IN YELLOWSTONE BASIN STUDY AREA

	MINING AREA									
ITEM	-1- NORTH DAKOTA LIGNITE	-2- EASTERN MONTANA LIGNITE	-3- MONTANA POWDER R. LIGNITE	-4- MONTANA POWDER R. SUBBIT.	-5- WYOMING POWDER R, LIGNITE	-6- WYOMING POWDER R. SUBBIT.	TOTAL STUDY AREA	-8- COLORADO	-9- SOUTHERN WYOMING	TOTAL PIES REGIONS 7+8
COAL PRODUCTION (MILLION TONS/YEAR)	17.25	19.49	.00	84.65	37.96	3.47	162.82	20.00	13.65	196.47
BTU CONTENT (MILLION BTU/TON)	13.57	13.40	15.20	17.39	16.45	18.90		20.83	17.24	.
COAL CONSUMPTION (MILLION TONS/YEAR)										
STUDY AREA GENERATION	6.86	.12	.00	4.63	1.43	.00	13.05			
SYNGAS	10.30	.00	.00	.00	.00	.00	10.30			
STUDY AREA GENERATION										
(MEGAWATT CAPACITY)	2,914.	50.	.	1,369.	390.	.	4,723.			
(GIGAWATT-HOUR/YEAR)	9,191.	158.	.	8,395.	2,393.	.	20,136.			
WATER REQUIREMENT (ACRE-FEET/YEAR)										
MINES	345.	390.	.	1,693.	759.	69.	3,256.			
RECLAMATION	2,571.	1,748.	.	4,757.	1,063.	311.	10,450.			
SYNGAS	9,986.	.	.	.	.	.	9,986.			
STUDY AREA GENERATION	22,978.	394.	.	20,987.	5,982.	.	50,341.			
SLURRY PIPELINE	.	.	.	.	.	.	.			
TOTAL	35,879.	2,532.	.	27,437.	7,804.	381.	74,033.			
LABOR REQUIREMENT (MANYEAR-EQUIVALENT/YEAR)										
MINES	354.	361.	.	1,577.	702.	70.	3,064.			
SYNGAS	624.	.	.	.	.	.	624.			
STUDY AREA GENERATION	379.	7.	.	178.	51.	.	614.			
TOTAL	1,357.	367.	.	1,755.	753.	70.	4,302.			
CAPITAL REQUIREMENT (MILLION DOLLARS)										
MINES	49.	74.	.	364.	187.	10.	685.			
SYNGAS	998.	.	.	.	.	.	998.			
STUDY AREA GENERATION	557.	.	.	153.	.	.	710.			
TOTAL	1,603.	74.	.	517.	187.	10.	2,393.			

```
INTERNAL STATEMENT NUMBER    0. TIME = 13:43:53
   1 **         TITLE    YELLOWSTONE ENERGY STUDY - 2000 MOST PROBABLE SCENARIO
         C     THE UNITS USED IN THIS MODEL ARE:
         C
         C     DESCRIPTION                  SYMBOL          UNIT
         C     MINING                       MXXXXX          MILLION TONS/YEAR
         C     (BTU CONVERSION)             BCMXX           TRILLION BTU / YEAR
         C     TRANSPORTATION               TXXXXX          TRILLION BTU / YEAR
         C     ELECTRICITY GENERATION       CXXXXXX         GIGAWATT-HOUR/YEAR
         C     TRANSMISSION LINES           LXXXXXX         GIGAWATT-HOUR/YEAR
         C     WATER                        WATCOST         ACRE-FEET/YEAR
         C     LABOR                        LABCOST         MAN-YEAR/YEAR
         C     SYNTHETIC GAS                SYNGASMX        MILLION TONS OF COAL/YEAR
   2 **          CALL ENTER(LP)
   3 **          ASSIGN 100 TO KMAJER
   4 **          ASSIGN 101 TO KMINER
   5 **          ITIME=7
   6 **          ASSIGN 300 TO KTIME
   7 **          CALL DEVICE('DRUM1',DRUM,100000)
   8 **          CALL DEVICE('DRUM2',DRUM,200000)
   9 **          CALL DEVICE('DRUM3',DRUM,100000)
  10 **          CALL DEVICE('DRUM4',DRUM,100000)
  11 **          CALL DEVICE('TAPEA',TAPE,'A')
  12 **          CALL DEVICE ('TAPEC',TAPE,'C')
  13 **          CALL ATTACH(MATRIX,'DRUM1')
  14 **          CALL ATTACH(INVERSE,'DRUM2')
  15 **          CALL ATTACH(UTIL1,'DRUM3')
  16 **          CALL ATTACH(UTIL2,'DRUM4')
  17 **          CALL ATTACH ('INFILE','TAPEA',FORTRAN,OLD)
  18 **          CALL ATTACH(RESTART,'TAPEC')
  19 **          ADATA = '2000MP'
  20 **          CALL INPUT(FILE,'INFILE')
  21 **          ADATA='CMPLAN8'
  22 **          CALL REVISE
  23 **          AOBJ='TOTCOST'
  24 **          ARHS='RHS'
  25 **          ASSIGN 200 TO KINV
  26 **          ASSIGN 201 TO KNFS
  27 **          ASSIGN 202 TO KUBS
  28 **          IFREQ1=0
  29 **          INVTIME=0
  30 **          FOBJWT=1.
  31 **          ASSIGN 300 TO KMINER
  32 **          CALL OPTIMIZE
  33 **          ARHS='CHANGE'
  34 **          FTHETAR=0.
  35 **          FTHETARP=.7
  36 **          FTHETARM=1.5
  37 **          ASSIGN 400 TO KINV
  38 **          ASSIGN 500 TO KSOLTN
```

01 DEC 76 YELLOWSTONE ENERGY STUDY - 1985 MOST PROBABLE SCENARIO 111070 1. 1. 1.

ITEM	-1- NORTH DAKOTA LIGNITE	-2- EASTERN MONTANA LIGNITE	-3- MONTANA POWDER R. LIGNITE	-4- MONTANA POWDER R. SUBBIT.	-5- WYOMING POWDER R. LIGNITE	-6- WYOMING POWDER R. SUBBIT.	TOTAL STUDY AREA	-8- COLORADO	-9- SOUTHERN WYOMING	TOTAL PIES REGIONS 7+8
LAND REQUIREMENTS										
STRIP MINING (ACRES/YEAR)	661.	448.	.	1,219.	273.	80.	2,680.			
SITES (ACRES)										
MINES	518.	585.	.	2,539.	1,139.	104.	4,885.			
SYNGAS	499.	.	.	.	.	.	499.			
STUDY AREA GENERATION	2,914.	50.	.	1,369.	390.	.	4,723.			
TOTAL	3,931.	635.	.	3,908.	1,529.	104.	10,107.			
AIR POLLUTANT EMISSIONS (TONS/YEAR)										
PARTICULATES	5,611.	79.	.	4,197.	1,196.	.	11,084.			
SULFUR OXIDES	66,291.	946.	.	50,369.	14,356.	.	131,962.			
NITROGEN OXIDES	53,401.	789.	.	41,974.	11,963.	.	108,127.			

```
11 DEC 76                                                                  111070     0.   0.   2.

            CALL PARAMB
            ASSIGN 101 TO KMINER
            CALL SOLUTION
            ADATA='SUMTAB'
            CALL PUBLISH
        100 CALL CONDITION
            STOP
        101 EXIT
        200 CALL INVERT
            RETURN
        201 CALL OUTPUT(BYROWS,ROWS,LISTI)
            GO TO 210
        202 CALL OUTPUT(BYROWS,ROWS,LISTU)
        210 CALL SOLUTION
            CALL CONDITION
            STOP
        300 CALL SAVE
            CALL CONDITION
            STOP
        400 CALL INVERT
            CALL OPTIMIZE
            RETURN
        500 CALL SOLUTION
            WRITE ITCNT
            RETURN
            END
INTERNAL STATEMENT NUMBER    0. TIME = 13:43:55
INTERNAL STATEMENT NUMBER   1. TIME = 13:43:55
INTERNAL STATEMENT NUMBER   2. TIME = 13:43:55
INTERNAL STATEMENT NUMBER   3. TIME = 13:43:55
INTERNAL STATEMENT NUMBER   4. TIME = 13:43:55
INTERNAL STATEMENT NUMBER   5. TIME = 13:43:55
INTERNAL STATEMENT NUMBER   6. TIME = 13:43:55
INTERNAL STATEMENT NUMBER   7. TIME = 13:43:55
INTERNAL STATEMENT NUMBER   8. TIME = 13:43:55
INTERNAL STATEMENT NUMBER   9. TIME = 13:43:55
INTERNAL STATEMENT NUMBER  10. TIME = 13:43:55
INTERNAL STATEMENT NUMBER  11. TIME = 13:43:55
INTERNAL STATEMENT NUMBER  12. TIME = 13:43:55
INTERNAL STATEMENT NUMBER  13. TIME = 13:43:55
INTERNAL STATEMENT NUMBER  14. TIME = 13:43:55
INTERNAL STATEMENT NUMBER  15. TIME = 13:43:55
INTERNAL STATEMENT NUMBER  16. TIME = 13:43:55
INTERNAL STATEMENT NUMBER  17. TIME = 13:43:55
INTERNAL STATEMENT NUMBER  18. TIME = 13:43:55
INTERNAL STATEMENT NUMBER  19. TIME = 13:43:55
INTERNAL STATEMENT NUMBER  20. TIME = 13:43:55

 BUFFER SIZES (WORDS) ARE.. MATRIX =  2048 INVERSE =  2048

 MATRIX STATISTICS
 ROWS........     277
 COLUMNS.....     726
 RHS.........       2
 DENSITY.....    1.99
 ELEMENTS....    4003
 LARGEST.....    .173052+006
 SMALLEST....    .487000-003
 MAJOR ERRORS       0
 MINOR ERRORS       0
INTERNAL STATEMENT NUMBER  21. TIME = 13:44:14
INTERNAL STATEMENT NUMBER  22. TIME = 13:44:14
 ROWS
  AFTER          CM6EX
  G  CM1PLANS
  G  CM2PLANS
  G  CM3PLANS
  G  CM4PLANS
  G  CM5PLANS
   E CM6PLANS
 COLUMNS
  MODIFY
      CM1NMLO    CM1PLANS    0.317
      CM1NMLW    CM1PLANS    0.317
      CM1NMMO    CM1PLANS    0.317
      CM1NMMW    CM1PLANS    0.317
      CM1NBLO    CM1PLANS    0.163
      CM1NBLW    CM1PLANS    0.163
      CM1NBMO    CM1PLANS    0.163
      CM1NBMW    CM1PLANS    0.163
      CM1EMLO    CM1PLANS    0.317
      CM1EMMO    CM1PLANS    0.317
      CM1EBLO    CM1PLANS    0.163
      CM1EBMO    CM1PLANS    0.163
```

```
RHS
 MODIFY
    RHS        CM1PLANS      2914.
    RHS        CM2PLANS       50.
    RHS        CM3PLANS      0.
    RHS        CM4PLANS     1369.
    RHS        CM5PLANS     390.
    RHS        CM6PLANS      0.
ENDATA

BUFFER SIZES (WORDS) ARE.. MATRIX =  2048 INVERSE =  2048

MATRIX STATISTICS
ROWS........     283
COLUMNS.....     726
RHS.........       2
DENSITY.....    1.98
ELEMENTS....    4079
LARGEST.....    .173052+006
SMALLEST....    .487000-003
MAJOR ERRORS       0
MINOR ERRORS       0
NTERNAL STATEMENT NUMBER  23. TIME = 13:44:21
NTERNAL STATEMENT NUMBER  24. TIME = 13:44:21
```

```
CM2NMLD   CM2PLANS   0.317
CM2NMLW   CM2PLANS   0.317
CM2NMHD   CM2PLANS   0.317
CM2NMHW   CM2PLANS   0.317
CM2NBLD   CM2PLANS   0.163
CM2NBLW   CM2PLANS   0.163
CM2NBHD   CM2PLANS   0.163
CM2NBHW   CM2PLANS   0.163
CM2EMLD   CM2PLANS   0.317
CM2EMHD   CM2PLANS   0.317
CM2EBLD   CM2PLANS   0.163
CM2EBHD   CM2PLANS   0.163
CM3NMLD   CM3PLANS   0.317
CM3NMLW   CM3PLANS   0.317
CM3NMHD   CM3PLANS   0.317
CM3NMHW   CM3PLANS   0.317
CM3NBLD   CM3PLANS   0.163
CM3NBLW   CM3PLANS   0.163
CM3NBHD   CM3PLANS   0.163
CM3NBHW   CM3PLANS   0.163
CM3EMLD   CM3PLANS   0.317
CM3EMHD   CM3PLANS   0.317
CM3EBLD   CM3PLANS   0.163
CM3EBHD   CM3PLANS   0.163
CM4NMLD   CM4PLANS   0.317
CM4NMLW   CM4PLANS   0.317
CM4NMHD   CM4PLANS   0.317
CM4NMHW   CM4PLANS   0.317
CM4NBLD   CM4PLANS   0.163
CM4NBLW   CM4PLANS   0.163
CM4NBHD   CM4PLANS   0.163
CM4NBHW   CM4PLANS   0.163
CM4EMLD   CM4PLANS   0.317
CM4EMHD   CM4PLANS   0.317
CM4EBLD   CM4PLANS   0.163
CM4EBHD   CM4PLANS   0.163
CM5NMLD   CM5PLANS   0.317
CM5NMLW   CM5PLANS   0.317
CM5NMHD   CM5PLANS   0.317
CM5NMHW   CM5PLANS   0.317
CM5NBLD   CM5PLANS   0.163
CM5NBLW   CM5PLANS   0.163
CM5NBHD   CM5PLANS   0.163
CM5NBHW   CM5PLANS   0.163
CM5EMLD   CM5PLANS   0.317
CM5EMHD   CM5PLANS   0.317
CM5EBLD   CM5PLANS   0.163
CM5EBHD   CM5PLANS   0.163
CM6NMLD   CM6PLANS   0.317
CM6NMLW   CM6PLANS   0.317
CM6NMHD   CM6PLANS   0.317
CM6NMHW   CM6PLANS   0.317
CM6NBLD   CM6PLANS   0.163
CM6NBLW   CM6PLANS   0.163
CM6NBHD   CM6PLANS   0.163
CM6NBHW   CM6PLANS   0.163
CM6EMLD   CM6PLANS   0.317
CM6EMHD   CM6PLANS   0.317
CM6EBLD   CM6PLANS   0.163
CM6EBHD   CM6PLANS   0.163
```

```
 131 NON-BASIC SLACKS. COMPLETELY TRIANGULARIZED   39 ROWS AND  241 COLS.
   3 IN NON-COMPLETELY TRIANGULARIZED PART. OF THESE:    1 WHERE NOT TRIANGULARIZED AND    0 WERE REJECTED FOR TOO SMALL A PIVOT.
MATRIX TO BE INVERTED HAD  283 COLS AND    762 ELEMENTS.    INVERSE HAS  136 COLS AND    615 ELEMENTS.

       564   MS FOR      INVERT
INTERNAL STATEMENT NUMBER  48. TIME = 13:44:29
INTERNAL STATEMENT NUMBER  32. TIME = 13:44:29

 NEGATIVE DJ COUNT =    67 SELECTED  15 VARIABLES BEST DJ =  -.193193+004

 NEGATIVE DJ COUNT =    62 SELECTED  15 VARIABLES BEST DJ =  -.104428+003

 NEGATIVE DJ COUNT =   134 SELECTED  15 VARIABLES BEST DJ =  -.898472+002

 NEGATIVE DJ COUNT =    64 SELECTED  15 VARIABLES BEST DJ =  -.278706+002

 NEGATIVE DJ COUNT =    97 SELECTED  15 VARIABLES BEST DJ =  -.999999+002

 NEGATIVE DJ COUNT =    34 SELECTED  12 VARIABLES BEST DJ =  -.794172+003

 NEGATIVE DJ COUNT =    12 SELECTED  12 VARIABLES BEST DJ =  -.807741+003

 NEGATIVE DJ COUNT =    77 SELECTED  15 VARIABLES BEST DJ =  -.807741+003

 NEGATIVE DJ COUNT =    47 SELECTED  15 VARIABLES BEST DJ =  -.173913+002

 NEGATIVE DJ COUNT =     9 SELECTED   9 VARIABLES BEST DJ =  -.430122+003

 NEGATIVE DJ COUNT =    11 SELECTED  11 VARIABLES BEST DJ =  -.746739+003

 NEGATIVE DJ COUNT =    45 SELECTED  15 VARIABLES BEST DJ =  -.471675+003

 NEGATIVE DJ COUNT =     5 SELECTED   5 VARIABLES BEST DJ =  -.151975+002
SOLUTION FEASIBLE AT ITERATION    229

 NEGATIVE DJ COUNT =   146 SELECTED  15 VARIABLES BEST DJ =  -.730272+000

 NEGATIVE DJ COUNT =   139 SELECTED  15 VARIABLES BEST DJ =  -.480000+001
INTERNAL STATEMENT NUMBER  47. TIME = 13:44:35

 176 NON-BASIC SLACKS. COMPLETELY TRIANGULARIZED   71 ROWS AND  212 COLS.
   0 IN NON-COMPLETELY TRIANGULARIZED PART. OF THESE:    0 WHERE NOT TRIANGULARIZED AND    0 WERE REJECTED FOR TOO SMALL A PIVOT.
MATRIX TO BE INVERTED HAD  283 COLS AND    889 ELEMENTS.    INVERSE HAS  174 COLS AND    780 ELEMENTS.

       511   MS FOR      INVERT
INTERNAL STATEMENT NUMBER  48. TIME = 13:44:36
INTERNAL STATEMENT NUMBER  32. TIME = 13:44:36

 NEGATIVE DJ COUNT =    86 SELECTED  15 VARIABLES BEST DJ =  -.375886+001

 NEGATIVE DJ COUNT =    61 SELECTED  15 VARIABLES BEST DJ =  -.440520+001
```

```
INTERNAL STATEMENT NUMBER  25. TIME = 13:44:21
INTERNAL STATEMENT NUMBER  26. TIME = 13:44:21
INTERNAL STATEMENT NUMBER  27. TIME = 13:44:21
INTERNAL STATEMENT NUMBER  28. TIME = 13:44:21
INTERNAL STATEMENT NUMBER  29. TIME = 13:44:21
INTERNAL STATEMENT NUMBER  30. TIME = 13:44:21
INTERNAL STATEMENT NUMBER  31. TIME = 13:44:21
INTERNAL STATEMENT NUMBER  32. TIME = 13:44:21

 NEGATIVE DJ COUNT =   213 SELECTED  15 VARIABLES BEST DJ =  -.100000+001

 NEGATIVE DJ COUNT =   157 SELECTED  15 VARIABLES BEST DJ =  -.108695+003
INTERNAL STATEMENT NUMBER  47. TIME = 13:44:22

  27 NON-BASIC SLACKS. COMPLETELY TRIANGULARIZED     5 ROWS AND  278 COLS.
   0 IN NON-COMPLETELY TRIANGULARIZED PART. OF THESE:    0 WHERE NOT TRIANGULARIZED AND    0 WERE REJECTED FOR TOO SMALL A PIVOT.
MATRIX TO BE INVERTED HAD  283 COLS AND    411 ELEMENTS.    INVERSE HAS   32 COLS AND    160 ELEMENTS.

      416   MS FOR      INVERT
INTERNAL STATEMENT NUMBER  48. TIME = 13:44:23
INTERNAL STATEMENT NUMBER  32. TIME = 13:44:23

 NEGATIVE DJ COUNT =   170 SELECTED  15 VARIABLES BEST DJ =  -.108753+003

 NEGATIVE DJ COUNT =   185 SELECTED  15 VARIABLES BEST DJ =  -.249877+004

 NEGATIVE DJ COUNT =   157 SELECTED  15 VARIABLES BEST DJ =  -.144122+003

 NEGATIVE DJ COUNT =   144 SELECTED  15 VARIABLES BEST DJ =  -.250647+004

 NEGATIVE DJ COUNT =   111 SELECTED  15 VARIABLES BEST DJ =  -.236684+004

 NEGATIVE DJ COUNT =   100 SELECTED  15 VARIABLES BEST DJ =  -.144122+003

 NEGATIVE DJ COUNT =   142 SELECTED  15 VARIABLES BEST DJ =  -.188086+004

 NEGATIVE DJ COUNT =   107 SELECTED  15 VARIABLES BEST DJ =  -.250647+004

 NEGATIVE DJ COUNT =   144 SELECTED  15 VARIABLES BEST DJ =  -.150542+003

 NEGATIVE DJ COUNT =    84 SELECTED  15 VARIABLES BEST DJ =  -.192699+004

 NEGATIVE DJ COUNT =   105 SELECTED  15 VARIABLES BEST DJ =  -.189870+004

 NEGATIVE DJ COUNT =   105 SELECTED  15 VARIABLES BEST DJ =  -.193193+004

 NEGATIVE DJ COUNT =    66 SELECTED  15 VARIABLES BEST DJ =  -.839970+002
 NTERNAL STATEMENT NUMBER  47. TIME = 13:44:28
```

```
11 DEC 76     YELLOWSTONE ENERGY STUDY - 2000 MOST PROBABLE SCENARIO                           111070     0.   1.   4.


NEGATIVE DJ COUNT =    50 SELECTED  15 VARIABLES BEST DJ =  -.425978+001

NEGATIVE DJ COUNT =    46 SELECTED  15 VARIABLES BEST DJ =  -.404251+001

NEGATIVE DJ COUNT =    34 SELECTED  15 VARIABLES BEST DJ =  -.585882+001

NEGATIVE DJ COUNT =    34 SELECTED  15 VARIABLES BEST DJ =  -.251937+000

NEGATIVE DJ COUNT =    24 SELECTED  15 VARIABLES BEST DJ =  -.449514+001

NEGATIVE DJ COUNT =    21 SELECTED  15 VARIABLES BEST DJ =  -.372006+001

NEGATIVE DJ COUNT =    13 SELECTED  13 VARIABLES BEST DJ =  -.294251+001

NEGATIVE DJ COUNT =     4 SELECTED   4 VARIABLES BEST DJ =  -.130000-001

NEGATIVE DJ COUNT =     0 SELECTED   0 VARIABLES BEST DJ =   .000000

OPTIMAL SOLUTION, OBJECTIVE VALUE =  .81891212+004
INTERNAL STATEMENT NUMBER  33. TIME = 13:44:40
INTERNAL STATEMENT NUMBER  34. TIME = 13:44:40
'NTERNAL STATEMENT NUMBER  35. TIME = 13:44:41
 NTERNAL STATEMENT NUMBER  36. TIME = 13:44:41
'NTERNAL STATEMENT NUMBER  37. TIME = 13:44:41
 NTERNAL STATEMENT NUMBER  38. TIME = 13:44:41
 NTERNAL STATEMENT NUMBER  39. TIME = 13:44:41

THETA AT MAXIMUM BELOW USER MAXIMUM, THETA =   .414625+000
 NTERNAL STATEMENT NUMBER  40. TIME = 13:46:08
 NTERNAL STATEMENT NUMBER  41. TIME = 13:46:08
```

```
11 DEC 76     YELLOWSTUNE ENERGY STUDY - 2000 MOST PROBABLE SCENARIO                111070    0.   2.   1.

IDENTIFIER SECTION

          PROBLEM... NAME.. ********
                     MODE.. LP
                     CLASS. LP
                     STATUS OPTIMAL*
          FUNCTIONAL NAME.. TOTCOST
                     OBJECT MINIMIZE
                     VALUE.    17479.665299
          RESTRAINT  NAME.. RHS
          ITERATION  COUNT.       015
          PARAMETRIC MODE.. PARARHS
          CHANGE COL....... CHANGE
          CHANGE ROW.......
                     VALUE.          .014625
```

```
11 DEC 76     YELLOWSTONE ENERGY STUDY - 2000 MOST PROBABLE SCENARIO                 111070     0.   2.   2.

SECTION 1 - ROWS                        PRIMAL-DUAL OUTPUT

NUMBER  ..NAME.. AT ...ACTIVITY...  SLACK ACTIVITY ..LOWER LIMIT. ..UPPER LIMIT. .DUAL ACTIVITY ..INPUT COST.. .REDUCED COST.
     1  LABCOST  FR   20938.861453  -20938.861453          NONE           NONE        .000000        .000000         .000000
     2  OPECOST  FR    2873.363030   -2873.363030          NONE           NONE        .000000        .000000         .000000
     3  MATCOST  FR  290626.189282 -290626.189282          NONE           NONE        .000000        .000000         .000000
     4  CAPRET   FR    5211.141905   -5211.141905          NONE           NONE        .000000        .000000         .000000
     5  RECFEE   FR   36792.506568  -36792.506568          NONE           NONE        .000000        .000000         .000000
     6  STRILAND FR    9442.260949   -9442.260949          NONE           NONE        .000000        .000000         .000000
     7  LANDUSE  FR   33986.501611  -33986.501611          NONE           NONE        .000000        .000000         .000000
     8  TOTCOST  FR   17479.665299  -17479.665299          NONE           NONE       1.000000        .000000        1.000000
     9  AM1      EQ        .000000        .000000       .000000        .000000        .000000        .000000         .000000
    10  AM2      EQ        .000000        .000000       .000000        .000000        .000000        .000000         .000000
    11  AM3      EQ        .000000        .000000       .000000        .000000        .000000        .000000         .000000
    12  AM4      EQ        .000000        .000000       .000000        .000000     -17.391480        .000000      -17.391480
    13  AM5      EQ        .000000        .000000       .000000        .000000        .000000        .000000         .000000
    14  AM6      EQ        .000000        .000000       .000000        .000000        .000000        .000000         .000000
    15  ALMM1    EQ        .000000        .000000       .000000        .000000        .000000        .000000         .000000
    16  ALMM2    EQ        .000000        .000000       .000000        .000000        .000000        .000000         .000000
    17  ALMM3    EQ        .000000        .000000       .000000        .000000        .000000        .000000         .000000
    18  ALMM4    EQ        .000000        .000000       .000000        .000000        .000000        .000000         .000000
    19  ALMM5    EQ        .000000        .000000       .000000        .000000        .000000        .000000         .000000
    20  ALMM6    EQ        .000000        .000000       .000000        .000000        .000000        .000000         .000000
    21  ARMM1    EQ        .000000        .000000       .000000        .000000        .000000        .000000         .000000
    22  ARMM2    EQ        .000000        .000000       .000000        .000000        .000000        .000000         .000000
    23  ARMM3    EQ        .000000        .000000       .000000        .000000        .000000        .000000         .000000
    24  ARMM4    EQ        .000000        .000000       .000000        .000000        .000000        .000000         .000000
    25  ARMM5    EQ        .000000        .000000       .000000        .000000        .000000        .000000         .000000
    26  ARMM6    EQ        .000000        .000000       .000000        .000000        .000000        .000000         .000000
    27  ASMM1    EQ        .000000        .000000       .000000        .000000        .000000        .000000         .000000
    28  ASMM2    EQ        .000000        .000000       .000000        .000000        .000000        .000000         .000000
    29  ASMM3    EQ        .000000        .000000       .000000        .000000        .000000        .000000         .000000
    30  ASMM4    EQ        .000000        .000000       .000000        .000000        .000000        .000000         .000000
    31  ASMM5    EQ        .000000        .000000       .000000        .000000        .000000        .000000         .000000
    32  ASMM6    EQ        .000000        .000000       .000000        .000000        .000000        .000000         .000000
    33  AMPM1    EQ        .000000        .000000       .000000        .000000        .000000        .000000         .000000
    34  AMPM2    EQ        .000000        .000000       .000000        .000000        .000000        .000000         .000000
    35  AMPM3    EQ        .000000        .000000       .000000        .000000        .000000        .000000         .000000
    36  AMPM4    EQ        .000000        .000000       .000000        .000000        .000000        .000000         .000000
    37  AMPM5    EQ        .000000        .000000       .000000        .000000        .000000        .000000         .000000
    38  AMPM6    EQ        .000000        .000000       .000000        .000000        .000000        .000000         .000000
    39  ACM1C    EQ        .000000        .000000       .000000        .000000        .000000        .000000         .000000
    40  ACM2C    EQ        .000000        .000000       .000000        .000000        .000000        .000000         .000000
    41  ACM3C    EQ        .000000        .000000       .000000        .000000        .000000        .000000         .000000
    42  ACM4C    EQ        .000000        .000000       .000000        .000000        .000000        .000000         .000000
    43  ACM5C    EQ        .000000        .000000       .000000        .000000        .000000        .000000         .000000
    44  ACM6C    EQ        .000000        .000000       .000000        .000000        .000000        .000000         .000000
    45  AMCM1    EQ        .000000        .000000       .000000        .000000        .000000        .000000         .000000
    46  AMCM2    EQ        .000000        .000000       .000000        .000000        .000000        .000000         .000000
    47  AMCM3    EQ        .000000        .000000       .000000        .000000        .000000        .000000         .000000
```

```
SECTION 1 - ROWS                          PRIMAL-DUAL OUTPUT

NUMBER  ..NAME.. AT ...ACTIVITY...   SLACK ACTIVITY  ..LOWER LIMIT.  ..UPPER LIMIT.  .DUAL ACTIVITY  ..INPUT COST..  .REDUCED COST.
     1  LABCOST  FR   20938.861453   -20938.861453            NONE            NONE         .000000         .000000         .000000
     2  OPECOST  FR    2873.363030    -2873.363030            NONE            NONE         .000000         .000000         .000000
     3  MATCOST  FR  290626.189282  -290626.189282            NONE            NONE         .000000         .000000         .000000
     4  CAPRET   FR    5211.141905    -5211.141905            NONE            NONE         .000000         .000000         .000000
     5  RECFEE   FR   36792.506568   -36792.506568            NONE            NONE         .000000         .000000         .000000
     6  STRILAND FR    9442.260949    -9442.260949            NONE            NONE         .000000         .000000         .000000
     7  LANDUSE  FR   33986.501611   -33986.501611            NONE            NONE         .000000         .000000         .000000
     8  TOTCOST  FR   17479.665299   -17479.665299            NONE            NONE        1.000000         .000000        1.000000
     9  AM1      EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
    10  AM2      EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
    11  AM3      EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
    12  AM4      EQ        .000000         .000000         .000000         .000000      -17.391480         .000000      -17.391480
    13  AM5      EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
    14  AM6      EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
    15  ALMM1    EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
    16  ALMM2    EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
    17  ALMM3    EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
    18  ALMM4    EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
    19  ALMM5    EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
    20  ALMM6    EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
    21  ARMM1    EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
    22  ARMM2    EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
    23  ARMM3    EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
    24  ARMM4    EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
    25  ARMM5    EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
    26  ARMM6    EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
    27  ASMM1    EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
    28  ASMM2    EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
    29  ASMM3    EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
    30  ASMM4    EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
    31  ASMM5    EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
    32  ASMM6    EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
    33  AWPM1    EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
    34  AWPM2    EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
    35  AWPM3    EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
    36  AWPM4    EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
    37  AWPM5    EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
    38  AWPM6    EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
    39  ACM1C    EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
    40  ACM2C    EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
    41  ACM3C    EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
    42  ACM4C    EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
    43  ACM5C    EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
    44  ACM6C    EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
    45  AWCM1    EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
    46  AWCM2    EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
    47  AWCM3    EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
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11 DEC 76     YELLOWSTONE ENERGY STUDY - 2000 MOST PROBABLE SCENARIO                    111070     0.   2.   4.

SECTION 1 - ROWS                          PRIMAL-DUAL OUTPUT

NUMBER  ..NAME.. AT ...ACTIVITY...  BLACK ACTIVITY  ..LOWER LIMIT.  ..UPPER LIMIT.  .DUAL ACTIVITY  ..INPUT COST..  .REDUCED COST.
    95  MBL1NBL3 EQ       .000000         .000000         .000000         .000000         .014229         .000000         .014229
    96  MBL1NBH3 EQ       .000000         .000000         .000000         .000000         .011542         .000000         .011542
    97  MBL1EML3 EQ       .000000         .000000         .000000         .000000         .204937         .000000         .204937
    98  MBL1EMH3 EQ       .000000         .000000         .000000         .000000         .004258         .000000         .004258
    99  MBL1EBL3 EQ       .000000         .000000         .000000         .000000         .000000         .000000         .000000
   100  MBL1EBH3 FQ       .000000         .000000         .000000         .000000         .007113         .000000         .007113
   101  MBL2NML3 EQ       .000000         .000000         .000000         .000000         .021336         .000000         .021336
   102  MBL2NMH3 EQ       .000000         .000000         .000000         .000000         .013006         .000000         .013006
   103  MBL2NBL3 EQ       .000000         .000000         .000000         .000000         .013851         .000000         .013851
   104  MBL2NBH3 EQ       .000000         .000000         .000000         .000000         .011164         .000000         .011164
   105  MBL2EML3 EQ       .000000         .000000         .000000         .000000         .202550         .000000         .202550
   106  MBL2EMH3 EQ       .000000         .000000         .000000         .000000         .001871         .000000         .001871
   107  MBL2EBL3 EQ       .000000         .000000         .000000         .000000         .107125         .000000         .107125
   108  MBL2EBH3 EQ       .000000         .000000         .000000         .000000         .105684         .000000         .105684
   109  MBL3NML3 EQ       .000000         .000000         .000000         .000000         .021552         .000000         .021552
   110  MBL3NMH3 EQ       .000000         .000000         .000000         .000000         .014509         .000000         .014509
   111  MBL3NBL3 EQ       .000000         .000000         .000000         .000000         .013112         .000000         .013112
   112  MBL3NBH3 EQ       .000000         .000000         .000000         .000000         .010425         .000000         .010425
   113  MBL3EML3 EQ       .000000         .000000         .000000         .000000         .206475         .000000         .206475
   114  MBL3EMH3 EQ       .000000         .000000         .000000         .000000         .001871         .000000         .001871
   115  MBL3EBL3 EQ       .000000         .000000         .000000         .000000         .192063         .000000         .192063
   116  MBL3EBH3 EQ       .000000         .000000         .000000         .000000         .005546         .000000         .005546
   117  MBL4NML3 FQ       .000000         .000000         .000000         .000000         .021552         .000000         .021552
   118  MBL4NMH3 EQ       .000000         .000000         .000000         .000000         .014509         .000000         .014509
   119  MBL4NBL3 EQ       .000000         .000000         .000000         .000000         .016912         .000000         .016912
   120  MBL4NBH3 EQ       .000000         .000000         .000000         .000000         .010425         .000000         .010425
   121  MBL4EML3 EQ       .000000         .000000         .000000         .000000         .202766         .000000         .202766
   122  MBL4EMH3 EQ       .000000         .000000         .000000         .000000         .353385         .000000         .353385
   123  MBL4EBL3 EQ       .000000         .000000         .000000         .000000         .192063         .000000         .192063
   124  MBL4EBH3 EQ       .000000         .000000         .000000         .000000         .005546         .000000         .005546
   125  MBL5NML3 EQ       .000000         .000000         .000000         .000000         .000000         .000000         .000000
   126  MBL5NMH3 EQ       .000000         .000000         .000000         .000000         .014842         .000000         .014842
   127  MBL5NBL3 EQ       .000000         .000000         .000000         .000000         .000000         .000000         .000000
   128  MBL5NBH3 EQ       .000000         .000000         .000000         .000000         .000000         .000000         .000000
   129  MBL5EML3 EQ       .000000         .000000         .000000         .000000         .371098         .000000         .371098
   130  MBL5EMH3 FQ       .000000         .000000         .000000         .000000         .371098         .000000         .371098
   131  MBL5EBL3 EQ       .000000         .000000         .000000         .000000         .192234         .000000         .192234
   132  MBL5EBH3 EQ       .000000         .000000         .000000         .000000         .192234         .000000         .192234
   133  MBL6NML3 EQ       .000000         .000000         .000000         .000000         .000000         .000000         .000000
   134  MBL6NMH3 EQ       .000000         .000000         .000000         .000000         .166769         .000000         .166769
   135  MBL6NBL3 EQ       .000000         .000000         .000000         .000000         .000000         .000000         .000000
   136  MBL6NBH3 EQ       .000000         .000000         .000000         .000000         .000000         .000000         .000000
   137  MBL6EML3 EQ       .000000         .000000         .000000         .000000         .206808         .000000         .206808
   138  MBL6EMH3 EQ       .000000         .000000         .000000         .000000         .000000         .000000         .000000
   139  MBL6EBL3 EQ       .000000         .000000         .000000         .000000         .192234         .000000         .192234
   140  MBL6EBH3 EQ       .000000         .000000         .000000         .000000         .004349         .000000         .004349
   141  MBL8NML3 EQ       .000000         .000000         .000000         .000000         .235327         .000000         .235327
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11 DEC 76     YELLOWSTONE ENERGY STUDY - 2000 MOST PROBABLE SCENARIO                              111070     0.   2.   5.

SECTION 1 - ROWS                          PRIMAL-DUAL OUTPUT

NUMBER  ..NAME.. AT ...ACTIVITY...  SLACK ACTIVITY  ..LOWER LIMIT.  ..UPPER LIMIT.  .DUAL ACTIVITY  ..INPUT COST..  .REDUCED CO
   142  MALANMH3 EQ        .000000         .000000         .000000         .000000         .019567         .000000        .019
   143  MALANBL3 EQ        .000000         .000000         .000000         .000000         .013518         .000000        .013
   144  MBLANBH3 EQ        .000000         .000000         .000000         .000000         .010830         .000000        .010
   145  MALAEML3 EQ        .000000         .000000         .000000         .000000         .222502         .000000        .222
   146  MBLAEMH3 EQ        .000000         .000000         .000000         .000000         .002844         .000000        .002
   147  MALAEBL3 EQ        .000000         .000000         .000000         .000000         .205209         .000000        .205
   148  MBLAEBH3 EQ        .000000         .000000         .000000         .000000         .006588         .000000        .006
   149  MAL9NML3 EQ        .000000         .000000         .000000         .000000         .021588         .000000        .021
   150  MAL9NMH3 EQ        .000000         .000000         .000000         .000000         .023398         .000000        .023
   151  MBL9NBL3 EQ        .000000         .000000         .000000         .000000         .013139         .000000        .013
   152  MAL9NBH3 EQ        .000000         .000000         .000000         .000000         .010452         .000000        .010
   153  MBL9EML3 EQ        .000000         .000000         .000000         .000000         .222502         .000000        .222
   154  MBL9EMH3 EQ        .000000         .000000         .000000         .000000         .002123         .000000        .0021
   155  MBL9EPL3 EQ        .000000         .000000         .000000         .000000         .205209         .000000        .205
   156  MBL9EBH3 EQ        .000000         .000000         .000000         .000000         .006580         .000000        .0065
   157  MAEU4L4  EQ        .000000         .000000         .000000         .000000       22.086732         .000000      22.0867
   158  MBEU4H4  EQ        .000000         .000000         .000000         .000000         .000000         .000000        .0000
   159  MAEU5L4  EQ        .000000         .000000         .000000         .000000       22.256732         .000000      22.2567
   160  MBEU5H4  EQ        .000000         .000000         .000000         .000000         .000000         .000000        .0000
   161  MBEU6KL4 EQ        .000000         .000000         .000000         .000000       21.650732         .000000      21.6507
   162  MBEU6KH4 EQ        .000000         .000000         .000000         .000000         .934900         .000000        .9349
   163  MBEU6LL4 EQ        .000000         .000000         .000000         .000000       22.061732         .000000      22.0617
   164  MAEU6LH4 EQ        .000000         .000000         .000000         .000000        1.090900         .000000       1.0909
   165  MBEU6ML4 EQ        .000000         .000000         .000000         .000000        1.276178         .000000       1.2761
   166  MBEU6MH4 EQ        .000000         .000000         .000000         .000000         .954900         .000000        .9549
   167  MAEU7L4  EQ        .000000         .000000         .000000         .000000       22.177732         .000000      22.1777
   168  MBEU7H4  EQ        .000000         .000000         .000000         .000000         .000000         .000000        .0000
   169  MAEU8L4  EQ        .000000         .000000         .000000         .000000       21.784732         .000000      21.7847
   170  MAEUAH4  EQ        .000000         .000000         .000000         .000000         .611900         .000000        .6119
   171  MASGASM1 EQ        .000000         .000000         .000000         .000000      -18.420000         .000000     -18.4200
   172  MASGASM2 EQ        .000000         .000000         .000000         .000000         .000000         .000000        .0000
   173  MASGASM3 EQ        .000000         .000000         .000000         .000000      -20.020000         .000000     -20.0200
   174  MASGASM4 EQ        .000000         .000000         .000000         .000000         .000000         .000000        .0000
   175  MBSGASM5 EQ        .000000         .000000         .000000         .000000      -22.660000         .000000     -22.6600
   176  MASGASM6 EQ        .000000         .000000         .000000         .000000         .000000         .000000        .0000
   177  RAILCAP2 BS      96.022066        3.977934            NONE      100.000000         .000000         .000000        .0000
   178  RAILCAP3 UL     100.000000         .000000            NONE      100.000000      347.971251         .000000     347.97125
   179  RAILCAP4 UL     100.000000         .000000            NONE      100.000000       65.007668         .000000      65.00766
   180  RAILCAP5 UL     100.000000         .000000            NONE      100.000000         .000000         .000000        .00000
   181  RAILCAP6 UL     100.000000         .000000            NONE      100.000000         .000000         .000000        .00000
   182  RAILCAP7 UL     100.000000         .000000            NONE      100.000000      347.971251         .000000     347.97125
   183  RAILCAP8 UL     100.000000         .000000            NONE      100.000000      282.963583         .000000     282.96358
   184  CM1EX    EQ    1220.000000         .000000     1220.000000     1220.000000         .610076         .000000        .61007
   185  CM2EX    EQ      50.000000         .000000       50.000000       50.000000         .596704         .000000        .59670
   186  CM3EX    EQ        .000000         .000000         .000000         .000000        1.135641         .000000       1.13564
   187  CM4EX    EQ     900.000000         .000000      900.000000      900.000000        1.108115         .000000       1.10811
   188  CM5EX    EQ     390.000000         .000000      390.000000      390.000000        1.163121         .000000       1.16312
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11 DEC 76     YELLOWSTONE ENERGY STUDY - 2000 MOST PROBABLE SCENARIO                        111070      0.   2.   7.

SECTION 1 - ROWS                          PRIMAL-DUAL OUTPUT

NUMBER  ..NAME.. AT ...ACTIVITY...  SLACK ACTIVITY  ..LOWER LIMIT.  ..UPPER LIMIT.  .DUAL ACTIVITY  ..INPUT COST..  .REDUCED COST.
   236  DEU6KEBL EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
   237  DEU6KEBH EQ    1747.379020         .000000     1747.379020     1747.379020        -.012509         .000000        -.012509
   238  DEU6LNML EQ   16435.073866         .000000    16435.073866    16435.073866        -.239417         .000000        -.239417
   239  DEU6LNMH EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
   240  DEU6LNBL EQ   12790.347313         .000000    12790.347313    12790.347313        -.212688         .000000        -.212688
   241  DEU6LNBH EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
   242  DEU6LEML EQ   10382.246363         .000000    10382.246363    10382.246363        -.241257         .000000        -.241257
   243  DEU6LEMH EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
   244  DEU6LEBL EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
   245  DEU6LEBH EQ    2446.207703         .000000     2446.207703     2446.207703        -.014045         .000000        -.014045
   246  DEU6MNML EQ   18782.941561         .000000    18782.941561    18782.941561        -.031562         .000000        -.031562
   247  DEU6MNMH EQ        .000000         .000000         .000000         .000000        -.024606         .000000        -.024606
   248  DEU6MNBL EQ   14617.628004         .000000    14617.628004    14617.628004        -.020605         .000000        -.020605
   249  DEU6MNBH EQ        .000000         .000000         .000000         .000000        -.017622         .000000        -.017622
   250  DEU6MEML EQ   11865.336611         .000000    11865.336611    11865.336611        -.019891         .000000        -.019891
   251  DEU6MEMH EQ        .000000         .000000         .000000         .000000        -.012247         .000000        -.012247
   252  DEU6MEBL EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
   253  DEU6MEBH EQ    2795.314732         .000000     2795.314732     2795.314732        -.012706         .000000        -.012706
   254  DEU7NML  EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
   255  DEU7NMH  EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
   256  DEU7NBL  EQ   95199.688787         .000000    95199.688787    95199.688787        -.213755         .000000        -.213755
   257  DEU7NBH  EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
   258  DEU7EML  EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
   259  DEU7EMH  EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
   260  DEU7EBL  EQ    9315.623447         .000000     9315.623447     9315.623447        -.221751         .000000        -.221751
   261  DEU7EBH  EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
   262  DEU8NML  EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
   263  DEU8NMH  EQ   20018.952953         .000000    20018.952953    20018.952953        -.025225         .000000        -.025225
   264  DEU8NBL  EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
   265  DEU8NBH  EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
   266  DEU8EML  EQ    5482.455456         .000000     5482.455456     5482.455456        -.238307         .000000        -.238307
   267  DEU8EMH  EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
   268  DEU8EBL  EQ   45050.601619         .000000    45050.601619    45050.601619        -.217880         .000000        -.217880
   269  DEU8EBH  EQ   16597.949504         .000000    16597.949504    16597.949504        -.009327         .000000        -.009327
   270  DICD4L   EQ    1191.143349         .000000     1191.143349     1191.143349      -22.306732         .000000      -22.306732
   271  DICD4H   EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
   272  DICD5L   EQ     210.201767         .000000      210.201767      210.201767      -22.470732         .000000      -22.470732
   273  DICD5H   EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
   274  DICD6KL  EQ      61.308848         .000000       61.308848       61.308848      -22.061732         .000000      -22.061732
   275  DICD6KH  EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
   276  DICD6LL  EQ      85.832388         .000000       85.832388       85.832388      -22.260732         .000000      -22.260732
   277  DICD6LH  EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
   278  DICD6ML  EQ      98.094158         .000000       98.094158       98.094158       -1.476178         .000000       -1.476178
   279  DICD6MH  EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
   280  DICD7L   EQ      11.677876         .000000       11.677876       11.677876      -22.334732         .000000      -22.334732
   281  DICD7H   EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
   282  DICD8L   EQ      93.423008         .000000       93.423008       93.423008      -21.823732         .000000      -21.823732
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SECTION 1 - ROWS                           PRIMAL-DUAL OUTPUT

NUMBER  ..NAME.. AT ...ACTIVITY...  BLACK ACTIVITY  ..LOWER LIMIT.  ..UPPER LIMIT.  .DUAL ACTIVITY  ..INPUT COST..  .REDUCED COS
   189  CM6EX    EQ       .000000          .000000         .000000         .000000         .082308         .000000         .0823
   190  CM1PLANS BS    9179.426355     6265.426355     2914.000000            NONE         .000000         .000000         .0000
   191  CM2PLANS LL      50.000000         .000000       50.000000            NONE         .000000         .000000         .0000
   192  CM3PLANS LL        .000000         .000000         .000000            NONE         .000000         .000000         .0000
   193  CM4PLANS LL    1369.000000         .000000     1369.000000            NONE        -.036378         .000000         .0363
   194  CM5PLANS LL     390.000000         .000000      390.000000            NONE        -.022756         .000000         .0227
   195  CM6PLANS EQ        .000000         .000000         .000000         .000000        1.121977         .000000        1.1219
   196  CM1PAR   FR   29065.160612   -29065.160612            NONE            NONE         .000000         .000000         .00000
   197  CM2PAR   FR      78.864353      -78.864353            NONE            NONE         .000000         .000000         .00000
   198  CM3PAR   FR    4069.800000    -4069.800000            NONE            NONE         .000000         .000000         .00000
   199  CM4PAR   FR    3500.483830    -3500.483830            NONE            NONE         .000000         .000000         .00000
   200  CM5PAR   FR    4405.469018    -4405.469018            NONE            NONE         .000000         .000000         .00000
   201  CM6PAR   FR        .000000         .000000            NONE            NONE         .000000         .000000         .00000
   202  CM1SO2   FR  340402.247339  -340402.247339            NONE            NONE         .000000         .000000         .00000
   203  CM2SO2   FR     946.372240     -946.372240            NONE            NONE         .000000         .000000         .00000
   204  CM3SO2   FR   44688.000000   -44688.000000            NONE            NONE         .000000         .000000         .00000
   205  CM4SO2   FR   42005.805965   -42005.805965            NONE            NONE         .000000         .000000         .00000
   206  CM5SO2   FR   49600.828221   -49600.828221            NONE            NONE         .000000         .000000         .00000
   207  CM6SO2   FR        .000000         .000000            NONE            NONE         .000000         .000000         .00000
   208  CM1NOX   FR  268830.906116  -268830.906116            NONE            NONE         .000000         .000000         .00000
   209  CM2NOX   FR     788.643533     -788.643533            NONE            NONE         .000000         .000000         .00000
   210  CM3NOX   FR   29830.000000   -29830.000000            NONE            NONE         .000000         .000000         .00000
   211  CM4NOX   FR   35004.838304   -35004.838304            NONE            NONE         .000000         .000000         .00000
   212  CM5NOX   FR   35503.140184   -35503.140184            NONE            NONE         .000000         .000000         .00000
   213  CM6NOX   FR        .000000         .000000            NONE            NONE         .000000         .000000         .00000
   214  DEU4NML  EQ   56053.805073         .000000    56053.805073    56053.805073        -.239667         .000000        -.23966
   215  DEU4NMH  EQ        .000000         .000000         .000000         .000000         .000000         .000000         .00000
   216  DEU4NBL  EQ   52041.961990         .000000    52041.961990    52041.961990        -.212918         .000000        -.21291
   217  DEU4NBH  EQ        .000000         .000000         .000000         .000000         .000000         .000000         .00000
   218  DEU4EML  EQ  106361.694339         .000000   106361.694339   106361.694339        -.241524         .000000        -.24152
   219  DEU4EMH  EQ        .000000         .000000         .000000         .000000         .000000         .000000         .00000
   220  DEU4EBL  EQ        .000000         .000000         .000000         .000000         .000000         .000000         .00000
   221  DEU4EBH  EQ        .000000         .000000         .000000         .000000         .000000         .000000         .00000
   222  DEU5NML  EQ   26859.115147         .000000    26859.115147    26859.115147        -.235867         .000000        -.23586
   223  DEU5NMH  EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
   224  DEU5NBL  EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
   225  DEU5NBH  EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
   226  DEU5EML  EQ   24123.419044         .000000    24123.419044    24123.419044        -.243334         .000000        -.243334
   227  DEU5EMH  EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
   228  DEU5EBL  EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
   229  DEU5EBH  EQ        .000000         .000000         .000000         .000000         .000000         .000000         .000000
   230  DEU6KNML EQ   11739.338476         .000000    11739.338476    11739.338476        -.037863         .000000        -.037863
   231  DEU6KNMH EQ        .000000         .000000         .000000         .000000        -.028616         .000000        -.028616
   232  DEU6KNBL EQ    9135.786718         .000000     9135.786718     9135.786718        -.021725         .000000        -.02172
   233  DEU6KNBH EQ        .000000         .000000         .000000         .000000        -.018742         .000000        -.018742
   234  DEU6KEML EQ    7416.065866         .000000     7416.065866     7416.065866        -.239010         .000000        -.239010
   235  DEU6KEMH EQ        .000000         .000000         .000000         .000000        -.016257         .000000        -.016257
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11 DEC 76     YELLOWSTONE ENERGY STUDY - 2000 MOST PROBABLE SCENARIO                     111070     0.   2.   9.

SECTION 2 - COLUMNS                    PRIMAL-DUAL OUTPUT

NUMBER  ..NAME.. AT ...ACTIVITY...  ..INPUT COST..  ..LOWER LIMIT.  ..UPPER LIMIT.  .REDUCED COST.
   284  M1EL11   UL       1.600000        5.350000        .000000        1.600000       -1.330000
   285  M1EL12   UL       1.600000        6.340000        .000000        1.600000        -.340000
   286  M1EL13   EQ        .000000        7.930000        .000000         .000000        1.250000
   287  M1EM11   UL       3.400000        5.350000        .000000        3.400000       -1.330000
   288  M1EM12   UL        .567000        6.340000        .000000         .567000        -.340000
   289  M1EM13   LL        .000000        7.930000        .000000        3.400000        1.250000
   290  M2EL11   UL       3.000000        5.580000        .000000        3.000000       -3.350000
   291  M2EL12   UL       3.000000        7.150000        .000000        3.000000       -1.780000
   292  M2EL13   EQ        .000000       10.100000        .000000         .000000        1.170000
   293  M2EM11   EQ        .000000        5.580000        .000000         .000000       -1.390000
   294  M2EM12   EQ        .000000        7.150000        .000000         .000000         .180000
   295  M2EM13   EQ        .000000       10.100000        .000000         .000000        3.130000
   296  M3EL11   EQ        .000000        5.010000        .000000         .000000       -1.200000
   297  M3EL12   EQ        .000000        5.960000        .000000         .000000        -.250000
   298  M3EL13   EQ        .000000        9.840000        .000000         .000000        3.630000
   299  M3EM11   EQ        .000000        5.010000        .000000         .000000       -2.440000
   300  M3EM12   EQ        .000000        5.960000        .000000         .000000       -1.490000
   301  M3EM13   EQ        .000000        9.840000        .000000         .000000        2.390000
   302  M4EL11   UL       9.200000        5.010000        .000000        9.200000       -2.440000
   303  M4EL12   UL       5.400000        5.960000        .000000        5.400000       -1.490000
   304  M4EL13   LL        .000000        9.810000        .000000        3.600000        2.360000
   305  M4EM11   LL        .000000        5.010000        .000000         .800000       10.408393
   306  M4EM12   LL        .000000        5.960000        .000000         .600000       11.358393
   307  M4EM13   LL        .000000        9.810000        .000000         .400000       15.208393
   308  M5EL11   UL       1.600000        4.080000        .000000        1.600000       -1.020000
   309  M5EL12   LL        .000000        5.340000        .000000        1.600000         .240000
   310  M5EL13   LL        .000000        7.230000        .000000        2.000000        2.130000
   311  M5EM11   UL        .400000        4.080000        .000000         .400000       -1.020000
   312  M5EM12   LL        .000000        5.340000        .000000         .400000         .240000
   313  M5EM13   EQ        .000000        7.230000        .000000         .000000        2.130000
   314  M6EL11   UL       1.000000        3.670000        .000000        1.000000      -55.555952
   315  M6EL12   UL       1.000000        4.390000        .000000        1.000000      -54.835952
   316  M6EL13   EQ        .000000        7.230000        .000000         .000000      -51.995952
   317  M6EM11   EQ        .000000        3.670000        .000000         .000000      339.828396
   318  M6EM12   EQ        .000000        4.390000        .000000         .000000      340.548396
   319  M6EM13   EQ        .000000        7.230000        .000000         .000000      343.388396
   320  M1NL11   BS      26.211382        6.680000        .000000       40.600000         .000000
   321  M1NL12   LL        .000000        7.690000        .000000        4.970000        1.010000
   322  M1NL13   LL        .000000        9.670000        .000000            NONE        2.990000
   323  M1NM11   BS      78.980876        6.680000        .000000       82.200000         .000000
   324  M1NM12   LL        .000000        7.690000        .000000       10.100000        1.010000
   325  M1NM13   LL        .000000        9.670000        .000000            NONE        2.990000
   326  M1       BS     112.359258         .000000        .000000      200.000000         .000000
   327  LMM1     BS    2255.653163         .000000        .000000            NONE         .000000
   328  RMM1     BS      60.590741         .000000        .000000            NONE         .000000
   329  SMM1     BS    4303.359587         .000000        .000000            NONE         .000000
   330  WPM1     LL        .000000         .000000        .000000            NONE         .000000
```

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11 DEC 76     YELLOWSTONE ENERGY STUDY - 2000 MOST PROBABLE SCENARIO                          111070     0.   2.   8.

SECTION 1 - ROWS                          PRIMAL-DUAL OUTPUT

NUMBER  ..NAME.. AT ...ACTIVITY...  SLACK ACTIVITY  ..LOWER LIMIT.  ..UPPER LIMIT.  .DUAL ACTIVITY  ..INPUT COST..  .REDUCED COST
   283  DICD8M   EQ        .000000         .000000         .000000         .000000         .000000         .000000          .00000
```

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11 DEC 76     YELLOWSTONE ENERGY STUDY - 2000 MOST PROBABLE SCENARIO                    111070     0.   2.  13.

SECTION 2 - COLUMNS                    PRIMAL-DUAL OUTPUT

NUMBER  ..NAME..  AT ...ACTIVITY...  ..INPUT COST..  ..LOWER LIMIT.  ..UPPER LIMIT.  .REDUCED COST.
   472  T304HR2   LL       .000000         .981000         .000000            NONE       24.367718
   473  T304HR4   LL       .000000         .981000         .000000            NONE       24.367718
   474  T305LR    LL       .000000        1.240000         .000000            NONE        2.036666
   475  T305HR    LL       .000000        1.240000         .000000            NONE       24.626718
   476  T306KLR   LL       .000000         .767000         .000000            NONE        1.972666
   477  T306KHR   LL       .000000         .767000         .000000            NONE       24.153718
   478  T306LLR2  LL       .000000         .981000         .000000            NONE        1.987666
   479  T306LLR4  LL       .000000         .981000         .000000            NONE        1.987666
   480  T306LHR2  LL       .000000         .981000         .000000            NONE       24.367718
   481  T306LHR4  LL       .000000         .981000         .000000            NONE       24.367718
   482  T306MLR   LL       .000000         .660000         .000000            NONE       22.451221
   483  T306MHR   LL       .000000         .660000         .000000            NONE       24.046718
   484  T307LR    LL       .000000        1.137000         .000000            NONE        2.069666
   485  T307HR    LL       .000000        1.137000         .000000            NONE       24.523718
   486  T308LR    LL       .000000         .656000         .000000            NONE        2.099666
   487  T308HR    LL       .000000         .656000         .000000            NONE       24.042718
   488  T304LU2   LL       .000000         .736000         .000000            NONE        1.916666
   489  T304LU4   LL       .000000         .736000         .000000            NONE        1.916666
   490  T304HU2   LL       .000000         .736000         .000000            NONE       24.122718
   491  T304HU4   LL       .000000         .736000         .000000            NONE       24.122718
   492  T305LU    LL       .000000         .927000         .000000            NONE        1.937666
   493  T305HU    LL       .000000         .927000         .000000            NONE       24.313718
   494  T306KLU   LL       .000000         .575000         .000000            NONE        1.991666
   495  T306KHU   LL       .000000         .575000         .000000            NONE       23.026818
   496  T306LLU2  LL       .000000         .736000         .000000            NONE        1.941666
   497  T306LLU4  LL       .000000         .736000         .000000            NONE        1.941666
   498  T306LHU2  LL       .000000         .736000         .000000            NONE       23.031818
   499  T306LHU4  LL       .000000         .736000         .000000            NONE       23.031818
   500  T306MLU   LL       .000000         .495000         .000000            NONE       22.486221
   501  T306MHU   LL       .000000         .495000         .000000            NONE       22.926818
   502  T307LU    LL       .000000         .853000         .000000            NONE        1.942666
   503  T307HU    LL       .000000         .853000         .000000            NONE       24.239718
   504  T308LU    LL       .000000         .493000         .000000            NONE        1.975666
   505  T308HU    LL       .000000         .493000         .000000            NONE       23.267818
   506  T404LR2   LL       .000000         .870000         .000000            NONE         .000000
   507  T404LR4   BS   1191.143349         .870000         .000000            NONE         .000000
   508  T404HR2   LL       .000000         .870000         .000000            NONE       21.567949
   509  T404HR4   LL       .000000         .870000         .000000            NONE       21.567949
   510  T405LR    LL       .000000        1.100000         .000000            NONE         .066000
   511  T405HR    LL       .000000        1.100000         .000000            NONE       21.797949
   512  T406KLR   LL       .000000         .680000         .000000            NONE         .055000
   513  T406KHR   LL       .000000         .680000         .000000            NONE       21.377949
   514  T406LLR2  LL       .000000         .880000         .000000            NONE         .056000
   515  T406LLR4  LL       .000000         .880000         .000000            NONE         .056000
   516  T406LHR2  LL       .000000         .880000         .000000            NONE       21.577949
   517  T406LHR4  LL       .000000         .880000         .000000            NONE       21.577949
   518  T406MLR   LL       .000000         .590000         .000000            NONE       20.550554
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SECTION 2 - COLUMNS                         PRIMAL-DUAL OUTPUT

NUMBER  ..NAME.. AT ...ACTIVITY...  ..INPUT COST..  ..LOWER LIMIT.  ..UPPER LIMIT.  .REDUCED COST.
   331  M2NL11   UL     24.100000        6.970000         .000000      24.100000      -1.960000
   332  M2NL12   BS       .782104        8.930000         .000000      79.499997        .000000
   333  M2NL13   LL       .000000       12.600000         .000000      55.300000       3.670000
   334  M2NM11   BS       .000000        6.970000         .000000       3.600000        .000000
   335  M2NM12   LL       .000000        8.930000         .000000      11.900000       1.960000
   336  M2NM13   LL       .000000       12.600000         .000000       8.270000       5.630000
   337  M2       BS     30.882104         .000000         .000000     200.000000        .000000
   338  LMM2     BS    578.883127         .000000         .000000           NONE        .000000
   339  RMM2     BS     13.464492         .000000         .000000           NONE        .000000
   340  SMM2     BS    710.288387         .000000         .000000           NONE        .000000
   341  WPM2     LL       .000000         .000000         .000000           NONE        .000000
   342  M3NL11   BS       .000000        6.210000         .000000      54.799999        .000000
   343  M3NL12   LL       .000000        7.450000         .000000     347.000000       1.240000
   344  M3NL13   LL       .000000       12.250000         .000000      72.200000       6.040000
   345  M3NM11   UL      7.470000        6.210000         .000000       7.470000      -1.240000
   346  M3NM12   BS     30.486072        7.450000         .000000      47.300000        .000000
   347  M3NM13   LL       .000000       12.250000         .000000       9.830000       4.800000
   348  M3       BS     37.956072         .000000         .000000     200.000000        .000000
   349  LMM3     BS    763.159476         .000000         .000000           NONE        .000000
   350  RMM3     BS     25.513753         .000000         .000000           NONE        .000000
   351  SMM3     BS    546.567437         .000000         .000000           NONE        .000000
   352  WPM3     LL       .000000         .000000         .000000           NONE        .000000
   353  M4NL11   UL     80.799997        6.210000         .000000      80.799997      -1.240000
   354  M4NL12   BS    104.600003        7.450000         .000000     376.000000        .000000
   355  M4NL13   LL       .000000       12.250000         .000000     235.000000       4.800000
   356  M4NM11   LL       .000000        6.210000         .000000       7.900000      11.606393
   357  M4NM12   LL       .000000        7.450000         .000000      37.200000      12.846393
   358  M4NM13   LL       .000000       12.250000         .000000      23.300000      17.646393
   359  M4       UL    200.000000         .000000         .000000     200.000000     -17.391480
   360  LMM4     BS   3920.000006         .000000         .000000           NONE        .000000
   361  RMM4     BS    121.965600         .000000         .000000           NONE        .000000
   362  SMM4     BS   2880.000000         .000000         .000000           NONE        .000000
   363  WPM4     LL       .000000         .000000         .000000           NONE        .000000
   364  M5NL11   BS    100.340837        5.100000         .000000     310.000000        .000000
   365  M5NL12   LL       .000000        6.670000         .000000     355.000000       1.570000
   366  M5NL13   LL       .000000        9.040000         .000000      26.000000       3.940000
   367  M5NM11   BS     26.104240        5.100000         .000000      34.500000        .000000
   368  M5NM12   LL       .000000        6.670000         .000000       3.530000       1.570000
   369  M5NM13   LL       .000000        9.040000         .000000        .260000       3.940000
   370  M5       BS    128.445077         .000000         .000000     200.000000        .000000
   371  LMM5     BS   2376.233920         .000000         .000000           NONE        .000000
   372  RMM5     BS     78.143057         .000000         .000000           NONE        .000000
   373  SMM5     BS    922.235651         .000000         .000000           NONE        .000000
   374  WPM5     LL       .000000         .000000         .000000           NONE        .000000
   375  M6NL11   UL       .370000        4.580000         .000000        .370000     -54.645952
   376  M6NL12   UL       .570000        5.490000         .000000        .570000     -53.735952
   377  M6NL13   UL       .530000        9.040000         .000000        .530000     -50.185952
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SECTION 2 - COLUMNS                          PRIMAL-DUAL OUTPUT

NUMBER  ..NAME.. AT ...ACTIVITY...  ..INPUT COST..  ..LOWER LIMIT.  ..UPPER LIMIT.  .REDUCED COST.
   378  M6NM11   EQ       .000000        4.580000         .000000         .000000      340.738396
   379  M6NM12   EQ       .000000        5.490000         .000000         .000000      341.648396
   380  M6NM13   EQ       .000000        9.040000         .000000         .000000      345.198396
   381  M6       BS      3.470000         .000000         .000000      200.000000         .000000
   382  LMM6     BS     70.250000         .000000         .000000           NONE          .000000
   383  RMM6     BS      1.246160         .000000         .000000           NONE          .000000
   384  SMM6     BS     79.810000         .000000         .000000           NONE          .000000
   385  MRM6     LL       .000000         .000000         .000000           NONE          .000000
   386  MRNL11   EQ     35.000000        7.460000       35.000000       35.000000     -443.638584
   387  MRNL12   EQ     12.000000       16.300000       12.000000       12.000000     -355.740070
   388  MRNM11   EQ       .000000        7.460000         .000000         .000000       -4.225417
   389  MRNM12   EQ       .000000       16.300000         .000000         .000000        6.662543
   390  M9NL11   EQ      7.000000        7.550000        7.000000        7.000000     -365.048828
   391  M9NL12   EQ       .000000       13.900000         .000000         .000000     -485.193119
   392  M9NM11   BS     25.666710        7.550000         .000000       27.000000         .000000
   393  M9NM12   EQ       .000000       13.900000         .000000         .000000        3.833333
   394  BCM1L    BS    399.068957         .000000         .000000           NONE          .000000
   395  BCM1M   -BS   1125.480000         .000000         .000000           NONE          .000000
   396  BCM2L    BS    413.969219         .000000         .000000           NONE          .000000
   397  BCM2M    BS       .000000         .000000         .000000           NONE          .000000
   398  BCM3L    LL       .000000         .000000         .000000           NONE          .037728
   399  BCM3M    BS    576.640000         .000000         .000000           NONE          .000000
   400  BCM4L    BS   3478.260870         .000000         .000000           NONE          .000000
   401  BCM4M    BS       .000000         .000000         .000000           NONE          .000000
   402  BCM5L    BS   1676.658500         .000000         .000000           NONE          .000000
   403  BCM5M    BS    435.925000         .000000         .000000           NONE          .000000
   404  BCM6L    BS     65.595463         .000000         .000000           NONE          .000000
   405  BCM6M    BS       .000000         .000000         .000000           NONE          .000000
   406  BCM8L1   BS    729.166667         .000000         .000000           NONE          .000000
   407  BCM8L2   BS    206.185567         .000000         .000000           NONE          .000000
   408  BCM8M1   BS       .000000         .000000         .000000           NONE          .000000
   409  BCM8M2   BS       .000000         .000000         .000000           NONE          .000000
   410  BCM9L1   BS    120.689655         .000000         .000000           NONE          .000000
   411  BCM9L2   BS       .000000         .000000         .000000           NONE          .000000
   412  BCM9M1   BS    442.529488         .000000         .000000           NONE          .000000
   413  BCM9M2   BS       .000000         .000000         .000000           NONE          .000000
   414  T104LR   LL       .000000         .980000         .000000           NONE          .020000
   415  T104MR   LL       .000000         .980000         .000000           NONE        22.326732
   416  T105LR   LL       .000000        1.220000         .000000           NONE          .096000
   417  T105MR   LL       .000000        1.220000         .000000           NONE        22.566732
   418  T106KLR  LL       .000000         .940000         .000000           NONE          .225000
   419  T106KMR  LL       .000000         .940000         .000000           NONE        22.286732
   420  T106LLR  LL       .000000        1.030000         .000000           NONE          .116000
   421  T106LMR  LL       .000000        1.030000         .000000           NONE        22.376732
   422  T106MLR  LL       .000000         .580000         .000000           NONE        20.450554
   423  T106MMR  LL       .000000         .580000         .000000           NONE        21.926732
   424  T107LR   LL       .000000        1.350000         .000000           NONE          .362000
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11 DEC 76     YELLOWSTONE ENERGY STUDY - 2000 MOST PROBABLE SCENARIO                    111070     0.   2.  12.

SECTION 2 - COLUMNS                         PRIMAL-DUAL OUTPUT

NUMBER  ..NAME.. AT ...ACTIVITY...  ..INPUT COST..  ..LOWER LIMIT.  ..UPPER LIMIT.  .REDUCED COST.
   425  T107MR   LL        .000000        1.350000         .000000           NONE       22.696732
   426  T108LR   LL        .000000         .970000         .000000           NONE       10.075130
   427  T108MR   LL        .000000         .970000         .000000           NONE       31.898862
   428  T1U4LU   BS        .000000         .740000         .000000           NONE         .000000
   429  T1U4MU   LL        .000000         .740000         .000000           NONE       22.066732
   430  T1U5LU   LL        .000000         .920000         .000000           NONE         .010000
   431  T1U5MU   LL        .000000         .920000         .000000           NONE       22.266732
   432  T1U6KLU  LL        .000000         .710000         .000000           NONE         .206000
   433  T1U6KMU  LL        .000000         .710000         .000000           NONE       21.121832
   434  T1U6LLU  LL        .000000         .770000         .000000           NONE         .055000
   435  T1U6LMU  LL        .000000         .770000         .000000           NONE       21.025832
   436  T1U6MLU  LL        .000000         .440000         .000000           NONE       20.510554
   437  T1U6MMU  LL        .000000         .440000         .000000           NONE       20.831832
   438  T1U7LU   LL        .000000        1.010000         .000000           NONE         .179000
   439  T1U7MU   LL        .000000        1.010000         .000000           NONE       22.356732
   440  T1U8LU   LL        .000000         .730000         .000000           NONE        9.874130
   441  T1U8MU   LL        .000000         .730000         .000000           NONE       31.046962
   442  T204LR   LL        .000000        1.050000         .000000           NONE        5.366101
   443  T204MR   LL        .000000        1.050000         .000000           NONE       27.528617
   444  T205LR   LL        .000000        1.380000         .000000           NONE        5.534101
   445  T205MR   LL        .000000        1.380000         .000000           NONE       27.858617
   446  T206KLR  LL        .000000        1.130000         .000000           NONE        5.693101
   447  T206KMR  LL        .000000        1.130000         .000000           NONE       27.608617
   448  T2U6LLR  LL        .000000        1.090000         .000000           NONE        5.454101
   449  T206LMR  LL        .000000        1.090000         .000000           NONE       27.568617
   450  T2U6MLR  BS      98.094158         .810000         .000000           NONE         .000000
   451  T206MMR  LL        .000000         .810000         .000000           NONE        1.329962
   452  T207LR   LL        .000000        1.500000         .000000           NONE        5.790101
   453  T207MR   LL        .000000        1.500000         .000000           NONE       27.978617
   454  T208LR   LL        .000000         .880000         .000000           NONE        5.681101
   455  T208MR   LL        .000000         .880000         .000000           NONE       27.358617
   456  T2U4LU   LL        .000000         .790000         .000000           NONE        5.328101
   457  T2U4MU   LL        .000000         .790000         .000000           NONE       27.268617
   458  T2U5LU   LL        .000000        1.040000         .000000           NONE        5.408101
   459  T2U5MU   LL        .000000        1.040000         .000000           NONE       27.518617
   460  T2U6KLU  LL        .000000         .840000         .000000           NONE        5.614101
   461  T2U6KMU  LL        .000000         .840000         .000000           NONE       26.363717
   462  T2U6LLU  LL        .000000         .820000         .000000           NONE        5.383101
   463  T2U6LMU  LL        .000000         .820000         .000000           NONE       26.207717
   464  T2U6MLU  BS     314.195251         .610000         .000000           NONE         .000000
   465  T2U6MMU  LL        .000000         .610000         .000000           NONE         .175062
   466  T2U7LU   LL        .000000        1.130000         .000000           NONE        5.577101
   467  T2U7MU   LL        .000000        1.130000         .000000           NONE       27.608617
   468  T2U8LU   LL        .000000         .660000         .000000           NONE        5.500101
   469  T2U8MU   LL        .000000         .660000         .000000           NONE       26.526717
   470  T304LR2  LL        .000000         .981000         .000000           NONE        1.941666
   471  T304LR4  LL        .000000         .981000         .000000           NONE        1.941666
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11 DEC 76     YELLOWSTONE ENERGY STUDY - 2000 MOST PROBABLE SCENARIO                  111070      0.   2.  15.

SECTION 2 - COLUMNS                      PRIMAL-DUAL OUTPUT

NUMBER  ..NAME.. AT ...ACTIVITY...  ..INPUT COST..  ..LOWER LIMIT.  ..UPPER LIMIT.  .REDUCED COST.
   566  T5U4LU3  LL        .000000         .650000         .000000            NONE          .030000
   567  T5U4LU7  LL        .000000         .650000         .000000            NONE          .030000
   568  T5U4MU3  LL        .000000         .650000         .000000            NONE        22.116732
   569  T5U4MU7  LL        .000000         .650000         .000000            NONE        22.116732
   570  T5U5LU3  LL        .000000         .790000         .000000            NONE          .000000
   571  T5U5LU7  BS     479.645645         .790000         .000000            NONE          .000000
   572  T5U5MU3  LL        .000000         .790000         .000000            NONE        22.256732
   573  T5U5MU7  LL        .000000         .790000         .000000            NONE        22.256732
   574  T5U6KLU3 LL        .000000         .446000         .000000            NONE          .062000
   575  T5U6KLU7 LL        .000000         .446000         .000000            NONE          .062000
   576  T5U6KMU3 LL        .000000         .446000         .000000            NONE        20.977832
   577  T5U6KMU7 LL        .000000         .446000         .000000            NONE        20.977832
   578  T5U6LLU3 LL        .000000         .595000         .000000            NONE          .000000
   579  T5U6LLU7 BS     392.592858         .595000         .000000            NONE          .000000
   580  T5U6LMU3 LL        .000000         .595000         .000000            NONE        20.970832
   581  T5U6LMU7 LL        .000000         .595000         .000000            NONE        20.970832
   582  T5U6MLU3 LL        .000000         .621000         .000000            NONE        20.811554
   583  T5U6MLU7 LL        .000000         .621000         .000000            NONE        20.811554
   584  T5U6MMU3 LL        .000000         .621000         .000000            NONE        21.132832
   585  T5U6MMU7 LL        .000000         .621000         .000000            NONE        21.132832
   586  T5U7LL   BS     658.764549         .711000         .000000            NONE          .000000
   587  T5U7MU   LL        .000000         .711000         .000000            NONE        22.177732
   588  T5U8LU   LL        .000000         .368000         .000000            NONE          .050000
   589  T5U8MU   LL        .000000         .368000         .000000            NONE        21.222832
   590  T6U4LR3  LL        .000000         .850000         .000000            NONE          .084000
   591  T6U4LR7  LL        .000000         .850000         .000000            NONE          .084000
   592  T6D4MR3  LL        .000000         .850000         .000000            NONE         1.474900
   593  T6D4MR7  LL        .000000         .850000         .000000            NONE         1.474900
   594  T6D5LR3  LL        .000000         .960000         .000000            NONE          .030000
   595  T6D5LR7  LL        .000000         .960000         .000000            NONE          .030000
   596  T6D5MR3  LL        .000000         .960000         .000000            NONE         1.584900
   597  T6D5MR7  LL        .000000         .960000         .000000            NONE         1.584900
   598  T6U6KLR3 LL        .000000         .540000         .000000            NONE          .019000
   599  T6D6KLR7 LL        .000000         .540000         .000000            NONE          .019000
   600  T6D6KMR3 LL        .000000         .540000         .000000            NONE         1.164900
   601  T6D6KMR7 LL        .000000         .540000         .000000            NONE         1.164900
   602  T6D6LLR3 BS      25.053274         .720000         .000000            NONE          .000000
   603  T6D6LLR7 LL        .000000         .720000         .000000            NONE          .000000
   604  T6D6LMR3 LL        .000000         .720000         .000000            NONE         1.344900
   605  T6D6LMR7 LL        .000000         .720000         .000000            NONE         1.344900
   606  T6D6MLR3 LL        .000000         .760000         .000000            NONE        20.824554
   607  T6D6MLR7 LL        .000000         .760000         .000000            NONE        20.824554
   608  T6D6MMR3 LL        .000000         .760000         .000000            NONE         1.384900
   609  T6U6MMR7 LL        .000000         .760000         .000000            NONE         1.384900
   610  T6D7LR   LL        .000000         .860000         .000000            NONE          .066000
   611  T6D7MR   LL        .000000         .860000         .000000            NONE         1.484900
   612  T6D8LR   LL        .000000         .450000         .000000            NONE          .167000
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SECTION 2 - COLUMNS                              PRIMAL-DUAL OUTPUT

NUMBER  ..NAME.. AT ...ACTIVITY...  ..INPUT COST..  ..LOWER LIMIT.  ..UPPER LIMIT.  .REDUCED COST.
   519  T4D6MHR  LL        .000000         .590000         .000000            NONE       21.287949
   520  T4D7LR   LL        .000000        1.010000         .000000            NONE         .112000
   521  T4D7HR   LL        .000000        1.010000         .000000            NONE       21.707949
   522  T4D8LR   LL        .000000         .590000         .000000            NONE         .203000
   523  T4D8HR   LL        .000000         .590000         .000000            NONE       21.287949
   524  T4U4LU2  BS    1624.089060         .650000         .000000            NONE         .000000
   525  T4U4LU4  BS     547.987086         .650000         .000000            NONE         .000000
   526  T4U4HU2  LL        .000000         .650000         .000000            NONE       21.347949
   527  T4U4HU4  LL        .000000         .650000         .000000            NONE       21.347949
   528  T4U5LU   BS      45.659919         .820000         .000000            NONE         .000000
   529  T4U5HU   LL        .000000         .820000         .000000            NONE       21.517949
   530  T4U6KLU  LL        .000000         .510000         .000000            NONE         .096000
   531  T4U6KHU  LL        .000000         .510000         .000000            NONE       20.273049
   532  T4U6LLU2 LL        .000000         .660000         .000000            NONE         .035000
   533  T4U6LLU4 LL        .000000         .660000         .000000            NONE         .035000
   534  T4U6LHU2 LL        .000000         .660000         .000000            NONE       20.267049
   535  T4U6LHU4 LL        .000000         .660000         .000000            NONE       20.267049
   536  T4U6MLU  LL        .000000         .440000         .000000            NONE       20.600554
   537  T4U6MHU  LL        .000000         .440000         .000000            NONE       20.165049
   538  T4U7LU   LL        .000000         .760000         .000000            NONE         .019000
   539  T4U7HU   LL        .000000         .760000         .000000            NONE       21.457949
   540  T4U8LU   LL        .000000         .440000         .000000            NONE         .092000
   541  T4U8HU   LL        .000000         .440000         .000000            NONE       20.526049
   542  T5D4LR3  LL        .000000         .932000         .000000            NONE         .092000
   543  T5D4LR7  LL        .000000         .932000         .000000            NONE         .092000
   544  T5D4HR3  LL        .000000         .932000         .000000            NONE       22.398732
   545  T5D4HR7  LL        .000000         .932000         .000000            NONE       22.398732
   546  T5D5LR3  LL        .000000        1.050000         .000000            NONE         .046000
   547  T5D5LR7  LL        .000000        1.050000         .000000            NONE         .046000
   548  T5D5HR3  LL        .000000        1.050000         .000000            NONE       22.516732
   549  T5D5HR7  LL        .000000        1.050000         .000000            NONE       22.516732
   550  T5D6KLR3 LL        .000000         .595000         .000000            NONE         .000000
   551  T5D6KLR7 BS      61.308848         .595000         .000000            NONE         .000000
   552  T5D6KHR3 LL        .000000         .595000         .000000            NONE       22.061732
   553  T5D6KHR7 LL        .000000         .595000         .000000            NONE       22.061732
   554  T5D6LLR3 BS       8.354173         .794000         .000000            NONE         .000000
   555  T5D6LLR7 BS      52.424942         .794000         .000000            NONE         .000000
   556  T5D6LHR3 LL        .000000         .794000         .000000            NONE       22.260732
   557  T5D6LHR7 LL        .000000         .794000         .000000            NONE       22.260732
   558  T5D6MLR3 LL        .000000         .828000         .000000            NONE       20.816554
   559  T5D6MLR7 LL        .000000         .828000         .000000            NONE       20.816554
   560  T5D6MHR3 LL        .000000         .828000         .000000            NONE       22.294732
   561  T5D6MHR7 LL        .000000         .828000         .000000            NONE       22.294732
   562  T5D7LR   LL        .000000         .946000         .000000            NONE         .076000
   563  T5D7HR   LL        .000000         .946000         .000000            NONE       22.412732
   564  T5D8LR   LL        .000000         .489000         .000000            NONE         .132000
   565  T5D8HR   LL        .000000         .489000         .000000            NONE       21.955732
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SECTION 2 - COLUMNS                          PRIMAL-DUAL OUTPUT

NUMBER   ..NAME..  AT  ...ACTIVITY...   ..INPUT COST..   ..LOWER LIMIT.   ..UPPER LIMIT.  .REDUCED COST.
   660   TBU6MLU   LL         .000000         .490000          .000000             NONE      20.866554
   661   TBU6MHU   LL         .000000         .490000          .000000             NONE        .096000
   662   TBU7LU    BS      308.831479         .525000          .000000             NONE        .000000
   663   TBU7HU    LL         .000000         .525000          .000000             NONE       1.085900
   664   TBUALU    BS      311.218104         .132000          .000000             NONE        .000000
   665   TBUAHU    LL         .000000         .132000          .000000             NONE        .081000
   666   TRD4LR    LL         .000000         .819000          .000000             NONE        .123000
   667   TRD4HR    LL         .000000         .819000          .000000             NONE       1.256900
   668   TRD5LR    LL         .000000        1.038000          .000000             NONE        .178000
   669   TRD5HR    LL         .000000        1.038000          .000000             NONE       1.475900
   670   TRDAKLR   LL         .000000         .646000          .000000             NONE        .195000
   671   TRDAKHR   LL         .000000         .646000          .000000             NONE       1.083900
   672   TRDALLR   LL         .000000         .848000          .000000             NONE        .196000
   673   TRD6LHR   LL         .000000         .848000          .000000             NONE       1.265900
   674   TRD6MLR   LL         .000000         .672000          .000000             NONE      20.806554
   675   TRD6MHR   LL         .000000         .672000          .000000             NONE       1.109900
   676   TRD7LR    LL         .000000         .840000          .000000             NONE        .116000
   677   TRD7HR    LL         .000000         .840000          .000000             NONE       1.277900
   678   TRDALR    LL         .000000         .226000          .000000             NONE        .013000
   679   TRDAHR    LL         .000000         .226000          .000000             NONE        .663900
   680   TRU4LU    LL         .000000         .630000          .000000             NONE        .154000
   681   TRU4HU    LL         .000000         .630000          .000000             NONE       1.067900
   682   TRU5LU    LL         .000000         .798000          .000000             NONE        .152000
   683   TRU5HU    LL         .000000         .798000          .000000             NONE       1.235900
   684   TRU6KLU   LL         .000000         .497000          .000000             NONE        .257000
   685   TRU6KHU   BS       17.211683         .497000          .000000             NONE        .000000
   686   TRU6LLU   LL         .000000         .653000          .000000             NONE        .202000
   687   TRU6LHU   BS       24.095146         .653000          .000000             NONE        .000000
   688   TRU6MLU   LL         .000000         .517000          .000000             NONE      20.851554
   689   TRU6MHU   BS       27.533850         .517000          .000000             NONE        .000000
   690   TRU7LU    LL         .000000         .646000          .000000             NONE        .079000
   691   TRU7HU    LL         .000000         .646000          .000000             NONE       1.083900
   692   TRUALU    BS      120.689655         .174000          .000000             NONE        .000000
   693   TRUAHU    BS      373.688809         .174000          .000000             NONE        .000000
   694   CM1NMLD   LL         .000000         .019900          .000000             NONE        .001592
   695   CM1NMLM   BS    11551.170440         .018800          .000000             NONE        .000000
   696   CM1NMHD   LL         .000000         .019900          .000000             NONE        .010218
   697   CM1NMHM   LL         .000000         .018800          .000000             NONE        .008576
   698   CM1NBLD   LL         .000000         .010300          .000000             NONE        .001043
   699   CM1NBLM   BS    26366.290342         .009700          .000000             NONE        .000000
   700   CM1NBHD   LL         .000000         .010300          .000000             NONE        .003976
   701   CM1NBHM   LL         .000000         .009700          .000000             NONE        .002909
   702   CM1EMLO   BS     3848.580442         .006300          .000000             NONE        .000000
   703   CM1EMHO   LL         .000000         .006300          .000000             NONE        .200679
   704   CM1EBLO   LL         .000000         .003300          .000000             NONE        .107592
   705   CM1EBHO   LL         .000000         .003300          .000000             NONE        .100478
   706   CM1C      BS       29.045771         .000000          .000000             NONE        .000000
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11 DEC 76      YELLOWSTONE ENERGY STUDY - 2000 MOST PROBABLE SCENARIO                        111070     0.   2.  16.

SECTION 2 - COLUMNS                             PRIMAL-DUAL OUTPUT

NUMBER  ..NAME.. AT ...ACTIVITY...   ..INPUT COST..   ..LOWER LIMIT.   ..UPPER LIMIT.  .REDUCED COST.
   613  T6D8HR   LL       .000000          .450000          .000000             NONE        1.074900
   614  T6U4LU3  LL       .000000          .640000          .000000             NONE         .094000
   615  T6U4LU7  LL       .000000          .640000          .000000             NONE         .094000
   616  T6U4MU3  LL       .000000          .640000          .000000             NONE        1.264900
   617  T6U4MU7  LL       .000000          .640000          .000000             NONE        1.264900
   618  T6U5LU3  LL       .000000          .720000          .000000             NONE         .004000
   619  T6U5LU7  LL       .000000          .720000          .000000             NONE         .004000
   620  T6U5MU3  LL       .000000          .720000          .000000             NONE        1.344900
   621  T6U5MU7  LL       .000000          .720000          .000000             NONE        1.344900
   622  T6U6KLU3 BS     40.542169          .310000          .000000             NONE         .000000
   623  T6U6KLU7 LL       .000000          .310000          .000000             NONE         .000000
   624  T6U6KMU3 LL       .000000          .310000          .000000             NONE         .000000
   625  T6U6KMU7 BS       .000000          .310000          .000000             NONE         .000000
   626  T6U6LLU3 LL       .000000          .540000          .000000             NONE         .019000
   627  T6U6LLU7 LL       .000000          .540000          .000000             NONE         .019000
   628  T6U6LMU3 LL       .000000          .540000          .000000             NONE         .074000
   629  T6U6LMU7 LL       .000000          .540000          .000000             NONE         .074000
   630  T6U6MLU3 LL       .000000          .570000          .000000             NONE       20.834554
   631  T6U6MLU7 LL       .000000          .570000          .000000             NONE       20.634554
   632  T6U6MMU3 LL       .000000          .570000          .000000             NONE         .240000
   633  T6U6MMU7 LL       .000000          .570000          .000000             NONE         .240000
   634  T6U7LU   LL       .000000          .650000          .000000             NONE         .013000
   635  T6U7MU   LL       .000000          .650000          .000000             NONE        1.274900
   636  T6U8LU   LL       .000000          .340000          .000000             NONE         .096000
   637  T6U8MU   LL       .000000          .340000          .000000             NONE         .353000
   638  T8D4LR   LL       .000000          .737000          .000000             NONE         .063000
   639  T8D4MR   LL       .000000          .737000          .000000             NONE        1.297900
   640  T8D5LR   BS    210.201767          .818000          .000000             NONE         .000000
   641  T8D5MR   LL       .000000          .816000          .000000             NONE        1.378900
   642  T8D6KLR  LL       .000000          .521000          .000000             NONE         .112000
   643  T8D6KMR  LL       .000000          .521000          .000000             NONE        1.081900
   644  T8D6LLR  LL       .000000          .689000          .000000             NONE         .061000
   645  T8D6LMR  LL       .000000          .689000          .000000             NONE        1.249900
   646  T8D6MLR  LL       .000000          .638000          .000000             NONE       20.814554
   647  T8D6MMR  LL       .000000          .638000          .000000             NONE        1.198900
   648  T8D7LR   BS     11.677876          .682000          .000000             NONE         .000000
   649  T8D7MR   LL       .000000          .682000          .000000             NONE        1.242900
   650  T8D8LR   BS     93.423008          .171000          .000000             NONE         .000000
   651  T8D8MR   LL       .000000          .171000          .000000             NONE         .731900
   652  T8U4LU   LL       .000000          .567000          .000000             NONE         .133000
   653  T8U4MU   LL       .000000          .567000          .000000             NONE        1.127900
   654  T8U5LU   LL       .000000          .629000          .000000             NONE         .025000
   655  T8U5MU   LL       .000000          .629000          .000000             NONE        1.189900
   656  T8U6KLU  LL       .000000          .401000          .000000             NONE         .203000
   657  T8U6KMU  LL       .000000          .401000          .000000             NONE         .027000
   658  T8U6LLU  LL       .000000          .530000          .000000             NONE         .121000
   659  T8U6LMU  BS       .000000          .530000          .000000             NONE         .000000
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SECTION 2 - COLUMNS                            PRIMAL-DUAL OUTPUT

NUMBER  ..NAME..  AT  ...ACTIVITY...   ..INPUT COST..  ..LOWER LIMIT.  ..UPPER LIMIT.  .REDUCED COST.
   754  CM5NMLO   LL          .000000          .019900          .000000            NONE          .016097
   755  CM5NMLW   LL          .000000          .018800          .000000            NONE          .014687
   756  CM5NMMO   LL          .000000          .019900          .000000            NONE          .001441
   757  CM5NMMW   BS          .000000          .018800          .000000            NONE          .000000
   758  CM5NBLO   LL          .000000          .010300          .000000            NONE          .009723
   759  CM5NBLW   LL          .000000          .009700          .000000            NONE          .008844
   760  CM5NBMO   LL          .000000          .010300          .000000            NONE          .009878
   761  CM5NBMW   LL          .000000          .009700          .000000            NONE          .008983
   762  CM5EMLO   BS          .000000          .006300          .000000            NONE          .000000
   763  CM5EMMO   BS          .000000          .006300          .000000            NONE          .000000
   764  CM5EBLO   BS      2392.638037          .003300          .000000            NONE          .000000
   765  CM5EBMO   BS          .000000          .003300          .000000            NONE          .000000
   766  CM5C      BS            25012          .000000          .000000            NONE          .000000
   767  WCM5      BS      5981.595092          .000000          .000000            NONE          .000000
   768  RCM5      BS          .000000          .000000          .000000            NONE          .000000
   769  CM6NMLO   LL          .000000          .019900          .000000            NONE          .407513
   770  CM6NMLW   LL          .000000          .018800          .000000            NONE          .384819
   771  CM6NMMO   BS          .000000          .019900          .000000            NONE          .000000
   772  CM6NMMW   BS          .000000          .018800          .000000            NONE          .000000
   773  CM6NBLO   LL          .000000          .010300          .000000            NONE          .222309
   774  CM6NBLW   LL          .000000          .009700          .000000            NONE          .200428
   775  CM6NBMO   LL          .000000          .010300          .000000            NONE          .002167
   776  CM6NBMW   BS          .000000          .009700          .000000            NONE          .000000
   777  CM6EMLO   LL          .000000          .006300          .000000            NONE          .193482
   778  CM6EMMO   LL          .000000          .006300          .000000            NONE          .178583
   779  CM6EBLO   LL          .000000          .003300          .000000            NONE          .017090
   780  CM6EBMO   BS          .000000          .003300          .000000            NONE          .000000
   781  CM6C      LL          .000000          .000000          .000000            NONE          .000000
   782  WCM6      LL          .000000          .000000          .000000            NONE          .008391
   783  RCM6      LL          .000000          .000000          .000000            NONE          .000000
   784  CM8NMLO   LL          .000000          .019900          .000000            NONE          .022753
   785  CM8NMLW   BS          .000000          .018800          .000000            NONE          .000000
   786  CM8NMMO   LL          .000000          .019900          .000000            NONE          .006840
   787  CM8NMMW   LL          .000000          .018800          .000000            NONE          .005123
   788  CM8NBLO   LL          .000000          .010300          .000000            NONE          .215475
   789  CM8NBLW   LL          .000000          .009700          .000000            NONE          .195388
   790  CM8NBMO   LL          .000000          .010300          .000000            NONE          .005415
   791  CM8NBMW   LL          .000000          .009700          .000000            NONE          .004254
   792  CM8EMLO   LL          .000000          .006300          .000000            NONE          .013317
   793  CM8EMMO   LL          .000000          .006300          .000000            NONE          .009402
   794  CM8EBLO   LL          .000000          .003300          .000000            NONE          .010288
   795  CM8EBMO   LL          .000000          .003300          .000000            NONE          .002209
   796  CM9NMLO   LL          .000000          .019900          .000000            NONE          .236030
   797  CM9NMLW   LL          .000000          .018800          .000000            NONE          .213319
   798  CM9NMMO   LL          .000000          .019900          .000000            NONE          .001582
   799  CM9NMMW   BS          .000000          .018800          .000000            NONE          .000000
   800  CM9NBLO   LL          .000000          .010300          .000000            NONE          .215429
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11 DEC 76     YELLOWSTONE ENERGY STUDY - 2000 MOST PROBABLE SCENARIO                           111070     0.   2. 18.

SECTION 2 - COLUMNS                          PRIMAL-DUAL OUTPUT

NUMBER  ..NAME.. AT ...ACTIVITY...  ..INPUT COST..  ..LOWER LIMIT.  ..UPPER LIMIT.  .REDUCED COST.
   707  WCM1     BS 104415.103058        .000000         .000000          NONE          .000000
   708  RCM1     BS    313.133889        .000000         .000000          NONE          .000000
   709  CM2NMLD  LL       .000000        .019900         .000000          NONE          .005892
   710  CM2NMLW  LL       .000000        .018800         .000000          NONE          .004126
   711  CM2NMMD  LL       .000000        .019900         .000000          NONE          .012926
   712  CM2NMMW  LL       .000000        .018800         .000000          NONE          .011254
   713  CM2NBLD  LL       .000000        .010300         .000000          NONE          .003177
   714  CM2NBLW  LL       .000000        .009700         .000000          NONE          .001978
   715  CM2NBMO  LL       .000000        .010300         .000000          NONE          .004648
   716  CM2NBMW  LL       .000000        .009700         .000000          NONE          .003554
   717  CM2EMLO  BS    157.728707        .006300         .000000          NONE          .000000
   718  CM2EMMO  LL       .000000        .006300         .000000          NONE          .199122
   719  CM2EBLO  BS       .000000        .003300         .000000          NONE          .000000
   720  CM2EBMO  BS       .000000        .003300         .000000          NONE          .000000
   721  CM2C     BS       .124763        .000000         .000000          NONE          .000000
   722  WCM2     BS    394.321767        .000000         .000000          NONE          .000000
   723  RCM2     BS       .000000        .000000         .000000          NONE          .000000
   724  CM3NMLD  LL       .000000        .019900         .000000          NONE          .002428
   725  CM3NMLW  LL       .000000        .018800         .000000          NONE          .000957
   726  CM3NMMO  LL       .000000        .019900         .000000          NONE          .011077
   727  CM3NMMW  LL       .000000        .018800         .000000          NONE          .009438
   728  CM3NBLO  LL       .000000        .010300         .000000          NONE          .000934
   729  CM3NBLW  BS       .000000        .009700         .000000          NONE          .000000
   730  CM3NBMO  LL       .000000        .010300         .000000          NONE          .005071
   731  CM3NBMW  LL       .000000        .009700         .000000          NONE          .004005
   732  CM3EMLO  LL       .000000        .006300         .000000          NONE          .163773
   733  CM3EMMO  LL       .000000        .006300         .000000          NONE          .369648
   734  CM3EMLO  BS       .000000        .003300         .000000          NONE          .000000
   735  CM3EBMO  LL       .000000        .003300         .000000          NONE          .187692
   736  CM3C     LL       .000000        .000000         .000000          NONE          .000000
   737  WCM3     BS       .000000        .000000         .000000          NONE          .000000
   738  RCM3     LL       .000000        .000000         .000000          NONE          .000000
   739  CM4NMLD  LL       .000000        .019900         .000000          NONE          .002528
   740  CM4NMLW  BS   1479.495268        .018800         .000000          NONE          .000000
   741  CM4NMMD  LL       .000000        .019900         .000000          NONE          .001859
   742  CM4NMMW  **      -.000000        .018800         .000000          NONE          .000000
   743  CM4NBLD  LL       .000000        .010300         .000000          NONE          .000000
   744  CM4NBLW  BS       .000000        .009700         .000000          NONE          .001886
   745  CM4NBMO  LL       .000000        .010300         .000000          NONE          .000000
   746  CM4NBMW  BS       .000000        .009700         .000000          NONE          .001255
   747  CM4EMLO  LL       .000000        .006300         .000000          NONE          .000000
   748  CM4EMMO  BS       .000000        .006300         .000000          NONE          .158487
   749  CM4EMLO  BS   5521.472393        .003300         .000000          NONE          .000000
   750  CM4EBMO  LL       .000000        .001300         .000000          NONE          .177240
   751  CM4C     BS      3.964820        .000000         .000000          NONE          .000000
   752  WCM4     BS  17502.419152        .000000         .000000          NONE          .000000
   753  RCM4     BS     18.493691        .000000         .000000          NONE          .000000
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11 DEC 76     YELLOWSTONE ENERGY STUDY - 2000 MOST PROBABLE SCENARIO                     111070      0.   2.  21.

SECTION 2 - COLUMNS                      PRIMAL-DUAL OUTPUT

NUMBER  ..NAME.. AT ...ACTIVITY...  ..INPUT COST..  ..LOWER LIMIT.  ..UPPER LIMIT.  .REDUCED COST.
   848  CU6KEBLO LL        .000000         .003300         .000000           NONE         .218530
   849  CU6KEBHO BS    1747.379020         .003300         .000000           NONE         .000000
   850  CU6LNMLW BS   16435.073866         .018800         .000000           NONE         .000000
   851  CU6LNMHW LL        .000000         .018800         .000000           NONE         .030254
   852  CU6LNBLW BS   12790.347313         .009720         .000000           NONE         .000000
   853  CU6LNBHW LL        .000000         .009720         .000000           NONE         .020247
   854  CU6LEMLO BS   10382.246363         .006300         .000000           NONE         .000000
   855  CU6LEMHO LL        .000000         .006300         .000000           NONE         .017918
   856  CU6LEBLO LL        .000000         .003300         .000000           NONE         .220608
   857  CU6LEBHO BS    2446.207703         .003300         .000000           NONE         .000000
   858  CU6MNMLW BS   18782.941561         .018800         .000000           NONE         .000000
   859  CU6MNMHW LL        .000000         .018800         .000000           NONE         .004220
   860  CU6MNBLW LL        .000000         .009720         .000000           NONE         .000856
   861  CU6MNBHW LL        .000000         .009720         .000000           NONE         .001313
   862  CU6MEMLO BS   11865.336611         .006300         .000000           NONE         .000000
   863  CU6MEMHO LL        .000000         .006300         .000000           NONE         .004223
   864  CU6MEBLO LL        .000000         .003300         .000000           NONE         .015870
   865  CU6MEBHO BS    2795.314732         .003300         .000000           NONE         .000000
   866  CU7NMLW  LL        .000000         .018800         .000000           NONE         .240577
   867  CU7NMHW  LL        .000000         .018800         .000000           NONE         .018800
   868  CU7NBLW  BS   95199.688787         .009720         .000000           NONE         .000000
   869  CU7NBHW  LL        .000000         .009720         .000000           NONE         .009720
   870  CU7EMLO  LL        .000000         .006300         .000000           NONE         .242493
   871  CU7EMHO  LL        .000000         .006300         .000000           NONE         .006300
   872  CU7EBLO  BS    9315.623447         .003300         .000000           NONE         .000000
   873  CU7EBHO  LL        .000000         .003300         .000000           NONE         .003300
   874  CU8NMLW  LL        .000000         .018800         .000000           NONE         .236647
   875  CU8NMHW  BS   20018.952953         .018800         .000000           NONE         .000000
   876  CU8NBLW  LL        .000000         .009720         .000000           NONE         .210140
   877  CU8NBHW  LL        .000000         .009720         .000000           NONE         .015625
   878  CU8EMLO  BS    5482.455456         .006300         .000000           NONE         .000000
   879  CU8EMHO  LL        .000000         .006300         .000000           NONE         .012817
   880  CU8EBLO  BS   37920.772403         .003300         .000000           NONE         .000000
   881  CU8EBHO  BS   14597.949504         .003300         .000000           NONE         .000000
   882  L1U6KNML BS   10406.459656         .011530         .000000           NONE         .000000
   883  L1U6KNMH BS        .000000         .011530         .000000           NONE         .000000
   884  L1U6KNBL BS    9135.786718         .005930         .000000           NONE         .000000
   885  L1U6KNBH BS        .000000         .005930         .000000           NONE         .000000
   886  L1U6KEML BS    3467.189587         .011530         .000000           NONE         .000000
   887  L1U6KEMH BS        .000000         .011530         .000000           NONE         .000000
   888  L1U6KEBL LL        .000000         .005930         .000000           NONE         .005930
   889  L1U6KEBH LL        .000000         .005930         .000000           NONE         .001317
   890  L1U6MNML LL        .000000         .009350         .000000           NONE         .004121
   891  L1U6MNMH LL        .000000         .009350         .000000           NONE         .001830
   892  L1U6MNBL BS   10617.628004         .004810         .000000           NONE         .000000
   893  L1U6MNBH BS        .000000         .004810         .000000           NONE         .000000
   894  L1U6MEML LL        .000000         .009350         .000000           NONE         .216939
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11 DEC 76     YELLOWSTONE ENERGY STUDY - 2000 MOST PROBABLE SCENARIO                    111070     0.   2.  20.

SECTION 2 - COLUMNS                          PRIMAL-DUAL OUTPUT

NUMBER  ..NAME.. AT ...ACTIVITY...  ..INPUT COST..  ..LOWER LIMIT.  ..UPPER LIMIT.  .REDUCED COST.
   801  CM9NBLW  LL         .000000         .009700         .000000            NONE         .195380
   802  CM9NBMD  LL         .000000         .010300         .000000            NONE         .004490
   803  CM9NBMW  LL         .000000         .009700         .000000            NONE         .003452
   804  CM9EMLO  LL         .000000         .006300         .000000            NONE         .012871
   805  CM9EMMO  LL         .000000         .006300         .000000            NONE         .008819
   806  CM9EBLO  LL         .000000         .003300         .000000            NONE         .009876
   807  CM9EBMO  LL         .000000         .003300         .000000            NONE         .001004
   808  SGASM1L  EQ         .000000         .000000         .000000         .000000       25.095805
   809  SGASM1M  EQ       83.000000         .000000       83.000000       83.000000       25.095805
   810  SYNGASM1 BS       83.000000       18.420000         .000000            NONE         .000000
   811  SGASM2L  EQ         .000000         .000000         .000000         .000000        8.926785
   812  SGASM2M  EQ         .000000         .000000         .000000         .000000        6.967491
   813  SYNGASM2 LL         .000000       18.900000         .000000            NONE       18.900000
   814  SGASM3L  EQ         .000000         .000000         .000000         .000000       25.650114
   815  SGASM3M  EQ       38.000000         .000000       38.000000       38.000000       27.461388
   816  SYNGASM3 BS       38.000000       20.020000         .000000            NONE         .000000
   817  SGASM4L  EQ         .000000         .000000         .000000         .000000       24.839617
   818  SGASM4M  EQ         .000000         .000000         .000000         .000000       11.992188
   819  SYNGASM4 LL         .000000       22.660000         .000000            NONE       22.660000
   820  SGASM5L  EQ         .000000         .000000         .000000         .000000       27.760816
   821  SGASM5M  EQ       26.500000         .000000       26.500000       26.500000       27.760816
   822  SYNGASM5 BS       26.500000       22.660000         .000000            NONE         .000000
   823  SGASM6L  EQ         .000000         .000000         .000000         .000000       59.214699
   824  SGASM6M  EQ         .000000         .000000         .000000         .000000     -336.094526
   825  SYNGASM6 LL         .000000       26.650000         .000000            NONE       26.650000
   826  CU4NMLW  BS    56053.605073         .018800         .000000            NONE         .000000
   827  CU4NMMW  LL         .000000         .018800         .000000            NONE         .018800
   828  CU4NBLW  BS    52041.961990         .009720         .000000            NONE         .000000
   829  CU4NBMW  LL         .000000         .009700         .000000            NONE         .009700
   830  CU4EMLO  BS   106361.694339         .006300         .000000            NONE         .000000
   831  CU4EMMO  LL         .000000         .006300         .000000            NONE         .006300
   832  CU4EBLO  LL         .000000         .003300         .000000            NONE         .220854
   833  CU4EBMO  LL         .000000         .003300         .000000            NONE         .003300
   834  CU5NMLW  BS    26859.115147         .013300         .000000            NONE         .000000
   835  CU5NMMW  LL         .000000         .018800         .000000            NONE         .018800
   836  CU5NBLW  LL         .000000         .009720         .000000            NONE         .214482
   837  CU5NBMW  LL         .000000         .009720         .000000            NONE         .009720
   838  CU5EMLO  BS    24123.419044         .006300         .000000            NONE         .000000
   839  CU5EMMO  LL         .000000         .006300         .000000            NONE         .006300
   840  CU5EBLO  LL         .000000         .003300         .000000            NONE         .222529
   841  CU5EBMO  LL         .000000         .003300         .000000            NONE         .003300
   842  CU6KNMLW LL         .000000         .018800         .000000            NONE         .149445
   843  CU6KNMMW BS         .000000         .018800         .000000            NONE         .000000
   844  CU6KNBLW LL         .000000         .009720         .000000            NONE         .169022
   845  CU6KNBMW **        -.000000         .009720         .000000            NONE         .000000
   846  CU6KEMLO BS     3806.778345         .006300         .000000            NONE         .000000
   847  CU6KEMMO BS         .000000         .006300         .000000            NONE         .000000
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11 DEC 76     YELLOWSTONE ENERGY STUDY - 2000 MOST PROBABLE SCENARIO                  111070     0.   2.  23.

SECTION 2 - COLUMNS                      PRIMAL-DUAL OUTPUT

NUMBER  ..NAME.. AT ...ACTIVITY...  ..INPUT COST..  ..LOWER LIMIT.  ..UPPER LIMIT.  .REDUCED COST.
   942  L4U6KEML BS        .000000         .013940         .000000            NONE         .000000
   943  L4U6KEMH LL        .000000         .013940         .000000            NONE         .369941
   944  L4U6KEBL LL        .000000         .007170         .000000            NONE         .220360
   945  L4U6KEBH LL        .000000         .007170         .000000            NONE         .000817
   946  L4U6MNML LL        .000000         .012740         .000000            NONE         .005101
   947  L4U6MNMH LL        .000000         .012740         .000000            NONE         .004238
   948  L4U6MNBL LL        .000000         .006550         .000000            NONE         .004717
   949  L4U6MNBH LL        .000000         .006550         .000000            NONE         .000500
   950  L4U6MEML LL        .000000         .012740         .000000            NONE         .217919
   951  L4U6MEMH LL        .000000         .012740         .000000            NONE         .392751
   952  L4U6MEBL LL        .000000         .006550         .000000            NONE         .219740
   953  L4U6MEBH BS        .000000         .006550         .000000            NONE         .000000
   954  L4UBNML  LL        .000000         .009120         .000000            NONE         .033043
   955  L4UBNMH  **       -.000000         .009120         .000000            NONE         .000000
   956  L4UBNBL  LL        .000000         .004690         .000000            NONE         .023062
   957  L4UBNBH  LL        .000000         .004690         .000000            NONE         .016262
   958  L4UBEML  LL        .000000         .091200         .000000            NONE         .077963
   959  L4UBEMH  LL        .000000         .091200         .000000            NONE         .483457
   960  L4UBEBL  BS    4974.299453         .004690         .000000            NONE         .000000
   961  L4UBEBH  LL        .000000         .004690         .000000            NONE         .001519
   962  L5UBNML  LL        .000000         .008750         .000000            NONE         .008750
   963  L5UBNMH  BS        .000000         .008750         .000000            NONE         .000000
   964  L5UBNBL  LL        .000000         .004500         .000000            NONE         .004500
   965  L5UBNBH  LL        .000000         .004500         .000000            NONE         .004500
   966  L5UBEML  LL        .000000         .008750         .000000            NONE         .182362
   967  L5UBEMH  LL        .000000         .008750         .000000            NONE         .420669
   968  L5UBEBL  BS    2155.529763         .004500         .000000            NONE         .000000
   969  L5UBEBH  LL        .000000         .004500         .000000            NONE         .208552
   970  L6UBNML  LL        .000000         .008750         .000000            NONE         .008750
   971  L6UBNMH  LL        .000000         .008750         .000000            NONE         .168639
   972  L6UBNBL  LL        .000000         .004500         .000000            NONE         .004500
   973  L6UBNBH  LL        .000000         .004500         .000000            NONE         .004500
   974  L6UBEML  BS        .000000         .008750         .000000            NONE         .000000
   975  L6UBEMH  LL        .000000         .008750         .000000            NONE         .008750
   976  L6UBEBL  BS        .000000         .004500         .000000            NONE         .000000
   977  L6UBEBH  BS        .000000         .004500         .000000            NONE         .000000
   978  L8U6KNML LL        .000000         .013100         .000000            NONE         .236451
   979  L8U6KNMH LL        .000000         .013100         .000000            NONE         .006202
   980  L8U6KNBL BS        .000000         .006720         .000000            NONE         .000000
   981  L8U6KNBH BS        .000000         .006720         .000000            NONE         .000000
   982  L8U6KEML LL        .000000         .013100         .000000            NONE         .021067
   983  L8U6KEMH BS        .000000         .013100         .000000            NONE         .000000
   984  L8U6KEBL LL        .000000         .006720         .000000            NONE         .234502
   985  L8U6KEBH LL        .000000         .006720         .000000            NONE         .001524
   986  L8UBNML  LL        .000000         .004680         .000000            NONE         .251774
   987  L8UBNMH  BS        .000000         .004680         .000000            NONE         .000000
   988  L8UBNBL  LL        .000000         .002410         .000000            NONE         .016603
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11 DEC 76     YELLOWSTONE ENERGY STUDY - 2000 MOST PROBABLE SCENARIO                      111070     0.   2.  22.

SECTION 2 - COLUMNS                 PRIMAL-DUAL OUTPUT

NUMBER  ..NAME.. AT ...ACTIVITY...  ..INPUT COST..  ..LOWER LIMIT.  ..UPPER LIMIT.  .REDUCED COST.
   895  L1U6MEMH LL        .000000         .009350         .000000            NONE         .001830
   896  L1U6MEBL LL        .000000         .004810         .000000            NONE         .004810
   897  L1U6MEBH BS        .000000         .004810         .000000            NONE         .000000
   898  L2U6KNML BS        .000000         .014180         .000000            NONE         .000000
   899  L2U6KNMH BS        .000000         .014180         .000000            NONE         .000000
   900  L2U6KNBL LL        .000000         .007290         .000000            NONE         .000940
   901  L2U6KNBH LL        .000000         .007290         .000000            NONE         .000940
   902  L2U6KEML BS     142.097934         .014180         .000000            NONE         .000000
   903  L2U6KEMH BS        .000000         .014180         .000000            NONE         .000000
   904  L2U6KEBL LL        .000000         .007290         .000000            NONE         .126198
   905  L2U6KEBH LL        .000000         .007290         .000000            NONE         .112091
   906  L2U6MNML LL        .000000         .010180         .000000            NONE         .002301
   907  L2U6MNMH BS        .000000         .010170         .000000            NONE         .000000
   908  L2U6MNBL BS        .000000         .005230         .000000            NONE         .000000
   909  L2U6MNBH BS        .000000         .005230         .000000            NONE         .000000
   910  L2U6MEML LL        .000000         .010170         .000000            NONE         .215109
   911  L2U6MEMH BS        .000000         .010170         .000000            NONE         .000000
   912  L2U6MEBL LL        .000000         .005230         .000000            NONE         .124138
   913  L2U6MEBH LL        .000000         .005230         .000000            NONE         .109834
   914  L3U6KNML BS        .000000         .013940         .000000            NONE         .000000
   915  L3U6KNMH LL        .000000         .013940         .000000            NONE         .001428
   916  L3U6KNBL BS        .000000         .007170         .000000            NONE         .000000
   917  L3U6KNBH BS        .000000         .007170         .000000            NONE         .000000
   918  L3U6KEML LL        .000000         .014180         .000000            NONE         .004357
   919  L3U6KEMH BS        .000000         .014180         .000000            NONE         .000000
   920  L3U6KEBL LL        .000000         .007170         .000000            NONE         .220360
   921  L3U6KEBH LL        .000000         .007170         .000000            NONE         .000817
   922  L3U6MNML LL        .000000         .012740         .000000            NONE         .005101
   923  L3U6MNMH LL        .000000         .012740         .000000            NONE         .004238
   924  L3U6MNBL LL        .000000         .006550         .000000            NONE         .000500
   925  L3U6MNBH LL        .000000         .006550         .000000            NONE         .000500
   926  L3U6MEML LL        .000000         .012470         .000000            NONE         .221766
   927  L3U6MEMH LL        .000000         .012470         .000000            NONE         .002300
   928  L3U6MEBL LL        .000000         .006550         .000000            NONE         .219740
   929  L3U6MEBH BS        .000000         .006550         .000000            NONE         .000000
   930  L3UANML  LL        .000000         .009120         .000000            NONE         .033043
   931  L3UANMH  BS        .000000         .009120         .000000            NONE         .000000
   932  L3UANBL  LL        .000000         .004690         .000000            NONE         .019245
   933  L3UANBH  LL        .000000         .004690         .000000            NONE         .016262
   934  L3UAEML  BS        .000000         .009120         .000000            NONE         .000000
   935  L3UAEMH  LL        .000000         .009120         .000000            NONE         .011197
   936  L3UAEBL  BS        .000000         .004690         .000000            NONE         .000000
   937  L3UAEBH  LL        .000000         .004690         .000000            NONE         .001519
   938  L4U6KNML BS    1332.878620         .013940         .000000            NONE         .000000
   939  L4U6KNMH LL        .000000         .013940         .000000            NONE         .001428
   940  L4U6KNBL LL        .000000         .007170         .000000            NONE         .004217
   941  L4U6KNBH BS        .000000         .007170         .000000            NONE         .000000
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11 DEC 76 YELLOWSTONE ENERGY STUDY - 2000 MOST PROBABLE SCENARIO 111070 1. 0. 1.

SUMMARY TABLE

RESOURCE REQUIREMENTS IN YELLOWSTONE BASIN STUDY AREA

MINING AREA

ITEM	-1- NORTH DAKOTA LIGNITE	-2- EASTERN MONTANA LIGNITE	-3- MONTANA POWDER R. LIGNITE	-4- MONTANA POWDER R. SUBBIT.	-5- WYOMING POWDER R. LIGNITE	-6- WYOMING POWDER R. SUBBIT.	TOTAL STUDY AREA	-8- COLORADO	-9- SOUTHERN WYOMING	TOTAL PIES REGIONS 7+8
COAL PRODUCTION (MILLION TONS/YEAR)	112.36	30.88	37.96	200.00	128.45	3.47	513.11	47.00	32.67	592.7
BTU CONTENT (MILLION BTU/TON)	13.57	13.40	15.20	17.39	16.45	18.90		20.83	17.24	
COAL CONSUMPTION (MILLION TONS/YEAR)										
STUDY AREA GENERATION	29.05	.12	.00	3.96	1.43	.00	34.56			
SYNGAS	83.00	.00	38.00	.00	26.50	.00	147.50			
STUDY AREA GENERATION										
(MEGAWATT CAPACITY)	9,182.	50.	.	1,370.	390.	.	10,992.			
(GIGAWATT-HOUR/YEAR)	41,766.	158.	.	7,001.	2,393.	.	51,317.			
WATER REQUIREMENT (ACRE-FEET/YEAR)										
MINES	2,247.	618.	759.	4,000.	2,569.	69.	10,262.			
RECLAMATION	16,742.	2,770.	2,133.	11,240.	3,596.	311.	36,793.			
SYNGAS	80,469.	.	40,014.	.	31,588.	.	152,071.			
STUDY AREA GENERATION	104,415.	394.	.	17,502.	5,982.	.	128,293.			
SLURRY PIPELINE	.	.	.	.	.	.	.			
TOTAL	203,872.	3,782.	42,906.	32,742.	43,735.	381.	327,419.			
LABOR REQUIREMENT (MAN-YEAR-EQUIVALENT/YEAR)										
MINES	2,256.	579.	763.	3,920.	2,376.	70.	9,964.			
SYNGAS	5,029.	.	2,502.	.	1,974.	.	9,505.			
STUDY AREA GENERATION	1,194.	7.	.	178.	51.	.	1,429.			
TOTAL	8,479.	585.	3,265.	4,098.	4,401.	70.	20,898.			
CAPITAL REQUIREMENT (MILLION DOLLARS)										
MINES	505.	112.	213.	1,016.	651.	10.	2,508.			
SYNGAS	8,044.	.	4,003.	.	3,160.	.	15,207.			
STUDY AREA GENERATION	2,609.	.	.	154.	.	.	2,764.			
TOTAL	11,158.	112.	4,215.	1,170.	3,811.	10.	20,478.			

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11 DEC 76     YELLOWSTONE ENERGY STUDY - 2000 MOST PROBABLE SCENARIO                    111070     0.   2.  24.

SECTION 2 - COLUMNS                    PRIMAL-DUAL OUTPUT

NUMBER  ..NAME.. AT ...ACTIVITY...  ..INPUT COST..  ..LOWER LIMIT.  ..UPPER LIMIT.  .REDUCED COST.
   989  L8UBNBM  LL       .000000         .002410         .000000           NONE         .013782
   990  L8UAEML  BS       .000000         .004680         .000000           NONE         .000000
   991  L8UAEMM  LL       .000000         .004680         .000000           NONE         .007666
   992  L8UAEBL  BS       .000000         .002410         .000000           NONE         .000000
   993  L8UAEBM  BS       .000000         .002410         .000000           NONE         .000000
   994  L9U6KNML BS       .000000         .013900         .000000           NONE         .000000
   995  L9U6KNMM LL       .000000         .013900         .000000           NONE         .011255
   996  L9U6KNBL BS       .000000         .007140         .000000           NONE         .000000
   997  L9U6KNBM BS       .000000         .007140         .000000           NONE         .000000
   998  L9U6KEML LL       .000000         .013900         .000000           NONE         .021867
   999  L9U6KEMM BS       .000000         .013900         .000000           NONE         .000000
  1000  L9U6KEBL LL       .000000         .007140         .000000           NONE         .234922
  1001  L9U6KEBM LL       .000000         .007140         .000000           NONE         .001944
  1002  L9UANML  LL       .000000         .004680         .000000           NONE         .027347
  1003  L9UBNMM  LL       .000000         .004680         .000000           NONE         .004023
  1004  L9UANBL  LL       .000000         .002410         .000000           NONE         .016206
  1005  L9UBNBM  LL       .000000         .002410         .000000           NONE         .013385
  1006  L9UAEML  BS       .000000         .004680         .000000           NONE         .000000
  1007  L9UAEMM  LL       .000000         .004680         .000000           NONE         .006909
  1008  L9UAEBL  BS       .000000         .002410         .000000           NONE         .000000
  1009  L9UAEBM  BS       .000000         .002410         .000000           NONE         .000000
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19 .OV 76 LLOWSTONE STUDY - 1985 HIGH SCENARIO 111070 1. 0. 1.

SUMMARY TABLE

RESOURCE REQUIREMENTS IN YELLOWSTONE BASIN STUDY AREA

	MINING AREA									
ITEM	-1- NORTH DAKOTA LIGNITE	-2- EASTERN MONTANA LIGNITE	-3- MONTANA POWDER R. LIGNITE	-4- MONTANA POWDER R. SUBBIT.	-5- WYOMING POWDER R. LIGNITE	-6- WYOMING POWDER R. SUBBIT.	TOTAL STUDY AREA	-8- COLORADO	-9- SOUTHERN WYOMING	TOTAL PIES REGIONS 7+8
COAL PRODUCTION (MILLION TONS/YEAR)	54.09	7.10	29.19	100.00	100.00	3.47	293.85	27.00	20.00	340.85
BTU CONTENT (MILLION BTU/TON)	13.57	13.40	13.20	17.39	16.45	16.90		20.83	17.24	
COAL CONSUMPTION (MILLION TONS/YEAR)										
STUDY AREA GENERATION	24.32	.12	.00	3.11	1.43	.00	28.99			
SYNGAS	10.30	.00	.00	.00	.00	.00	10.30			
STUDY AREA GENERATION										
(MEGAWATT CAPACITY)	8,870.	50.	.	900.	390.	.	10,210.			
(GIGAWATT-HOUR/YEAR)	34,198.	158.	.	5,521.	2,393.	.	42,270.			
WATER REQUIREMENT (ACRE-FEET/YEAR)										
MINES	1,082.	142.	584.	2,000.	2,000.	69.	5,877.			
RECLAMATION	8,060.	637.	1,640.	5,620.	2,800.	311.	19,068.			
SYNGAS	9,986.	.	.	.	.	.	9,986.			
STUDY AREA GENERATION	85,494.	394.	.	13,804.	5,982.	.	105,674.			
SLURRY PIPELINE	11,365.	.	.	24,376.	22,982.	.	58,724.			
TOTAL	115,987.	1,173.	2,224.	45,800.	33,764.	381.	199,329.			
LABOR REQUIREMENT (MAN-YEAR-EQUIVALENT/YEAR)										
MINES	1,091.	131.	540.	1,870.	1,850.	70.	5,552.			
SYNGAS	624.	.	.	.	.	.	624.			
STUDY AREA GENERATION	1,153.	7.	.	117.	51.	.	1,327.			
TOTAL	2,868.	138.	540.	1,987.	1,901.	70.	7,503.			
CAPITAL REQUIREMENT (MILLION DOLLARS)										
MINES	225.	18.	152.	446.	505.	10.	1,357.			
SYNGAS	998.	.	.	.	.	.	998.			
STUDY AREA GENERATION	2,510.	.	.	.	.	.	2,510.			
TOTAL	3,733.	18.	152.	446.	505.	10.	4,865.			

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11 DEC 76     YELLOWSTONE ENERGY STUDY - 2000 MOST PROBABLE SCENARIO                              111070     1.   1.   1.

                              -1-        -2-        -3-        -4-        -5-        -6-        TOTAL      -8-       -9-       TOTAL
       ITEM                   NORTH      EASTERN    MONTANA    MONTANA    WYOMING    WYOMING    STUDY      COLORADO  SOUTHERN  PIES
                              DAKOTA     MONTANA    POWDER R.  POWDER R.  POWDER R.  POWDER R.  AREA                 WYOMING   REGIONS
                              LIGNITE    LIGNITE    LIGNITE    SUBBIT.    LIGNITE    SUBBIT.                                   7+8
   LAND REQUIREMENTS
     STRIP MINING
         (ACRES/YEAR)           4,303.       710.       547.     2,880.       922.        80.     9,442.
     SITES
         (ACRES)
         MINES                  3,371.       926.     1,139.     6,000.     3,853.       104.    15,393.
         SYNGAS                 4,024.          .     2,001.          .     1,579.          .     7,605.
         STUDY AREA GENERATION  9,182.        50.          .     1,370.       390.          .    10,992.
         TOTAL                 16,577.       976.     3,140.     7,370.     5,823.       104.    33,990.

   AIR POLLUTANT EMISSIONS
   (TONS/YEAR)
         PARTICULATES          29,065.        79.     4,070.     3,500.     4,405.          .    41,120.
         SULFUR OXIDES        340,402.       946.    44,688.    42,006.    49,601.          .   477,643.
         NITROGEN OXIDES      268,831.       789.    29,830.    35,005.    35,503.          .   369,958.
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29 NOV 76 YELLOWSTONE ENERGY STUDY - 2000 HIGH SCENARIO 111070 1. 0. 1.

SUMMARY TABLE

RESOURCE REQUIREMENTS IN YELLOWSTONE BASIN STUDY AREA

MINING AREA

ITEM	-1- NORTH DAKOTA LIGNITE	-2- EASTERN MONTANA LIGNITE	-3- MONTANA POWDER R. LIGNITE	-4- MONTANA POWDER R. SUBBIT.	-5- WYOMING POWDER R. LIGNITE	-6- WYOMING POWDER R. SUBBIT.	TOTAL STUDY AREA	-8- COLORADO	-9- SOUTHERN WYOMING	TOTAL PIES REGIONS 7+8
COAL PRODUCTION (MILLION TONS/YEAR)	158.26	30.10	200.00	200.00	200.00	3.47	791.83	90.00	50.00	931.83
BTU CONTENT (MILLION BTU/TON)	13.57	13.40	15.20	17.39	16.45	18.90		20.83	17.24	
COAL CONSUMPTION (MILLION TONS/YEAR)										
STUDY AREA GENERATION	28.34	.12	.00	3.11	1.43	.00	33.01			
SYNGAS	104.00	.00	57.00	.00	44.50	.00	205.50			
STUDY AREA GENERATION										
(MEGAWATT CAPACITY)	8,873.	50.	.	900.	390.	.	10,214.			
(GIGAWATT-HOUR/YEAR)	40,806.	158.	.	5,521.	2,393.	.	48,878.			
WATER REQUIREMENT (ACRE-FEET/YEAR)										
MINES	3,165.	602.	4,000.	4,000.	4,000.	69.	15,837.			
RECLAMATION	23,580.	2,700.	11,240.	11,240.	5,600.	311.	54,671.			
SYNGAS	100,828.	.	60,021.	.	53,044.	.	213,893.			
STUDY AREA GENERATION	102,015.	394.	.	13,804.	5,982.	.	122,194.			
SLURRY PIPELINE	15,191.	10,851.	73,518.	26,563.	23,314.	.	149,437.			
TOTAL	244,779.	14,547.	148,779.	55,606.	91,940.	381.	556,032.			
LABOR REQUIREMENT (MAN-YEAR-EQUIVALENT/YEAR)										
MINES	3,300.	563.	3,975.	3,920.	3,700.	70.	15,529.			
SYNGAS	6,301.	.	3,752.	.	3,315.	.	13,369.			
STUDY AREA GENERATION	1,153.	7.	.	117.	51.	.	1,328.			
TOTAL	10,755.	569.	7,728.	4,037.	7,066.	70.	30,225.			
CAPITAL REQUIREMENT (MILLION DOLLARS)										
MINES	775.	108.	1,109.	1,016.	1,020.	10.	4,039.			
SYNGAS	10,079.	.	6,004.	.	5,307.	.	21,390.			
STUDY AREA GENERATION	2,508.	.	.	.	.	.	2,508.			
TOTAL	13,362.	108.	7,113.	1,016.	6,326.	10.	27,936.			

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29 NOV 76  LLOWSTONE STUDY - 1985 HIGH SCENARIO                                         111070     1.   1.   1.

                                   -1-       -2-       -3-       -4-       -5-       -6-      TOTAL       -8-       -9-      TOTAL
                                  NORTH    EASTERN   MONTANA   MONTANA   WYOMING   WYOMING    STUDY    COLORADO  SOUTHERN   PIES
           ITEM                   DAKOTA   MONTANA   POWDER R. POWDER R. POWDER R. POWDER R. AREA               WYOMING   REGIONS
                                 LIGNITE   LIGNITE   LIGNITE   SUBBIT.   LIGNITE   SUBBIT.                                7+8

     LAND REQUIREMENTS
       STRIP MINING
          (ACRES/YEAR)             2,072.      163.      420.    1,440.      718.       80.    4,893.
       SITES
          (ACRES)
          MINES                    1,623.      213.      876.    3,000.    3,000.      104.    8,815.
          SYNGAS                     499.        .         .         .         .         .       499.
          STUDY AREA GENERATION    8,870.       50.        .       900.      390.        .    10,210.
          TOTAL                   10,992.      263.      876.    3,900.    3,390.      104.   19,525.

     AIR POLLUTANT EMISSIONS
     (TONS/YEAR)
          PARTICULATES            18,114.       79.        .     2,761.    1,196.        .    22,150.
          SULFUR OXIDES          216,331.      946.        .    33,129.   14,356.        .   264,762.
          NITROGEN OXIDES        178,435.      789.        .    27,607.   11,963.        .   218,794.
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SUMMARY TABLE

RESOURCE REQUIREMENTS IN YELLOWSTONE BASIN STUDY AREA

MINING AREA

ITEM	-1- NORTH DAKOTA LIGNITE	-2- EASTERN MONTANA LIGNITE	-3- MONTANA POWDER R. LIGNITE	-4- MONTANA POWDER R. SUBBIT.	-5- WYOMING POWDER R. LIGNITE	-6- WYOMING POWDER R. SUBBIT.	TOTAL STUDY AREA	-8- COLORADO	-9- SOUTHERN WYOMING	TOTAL PIES REGIONS 7+8
COAL PRODUCTION (MILLION TONS/YEAR)	3.08	18.97	.00	83.13	37.96	3.47	146.61	20.00	13.27	179.88
BTU CONTENT (MILLION BTU/TON)	13.57	13.40	15.20	17.39	16.45	18.90		20.83	17.24	
COAL CONSUMPTION (MILLION TONS/YEAR)										
STUDY AREA GENERATION	3.04	.12	.00	3.11	1.43	.00	7.70			
SYNGAS	.00	.00	.00	.00	.00	.00	.00			
STUDY AREA GENERATION										
(MEGAWATT CAPACITY)	1,220.	50.	.	900.	390.	.	2,561.			
(GIGAWATT-HOUR/YEAR)	3,941.	158.	.	5,521.	2,393.	.	12,013.			
WATER REQUIREMENT (ACRE-FEET/YEAR)										
MINES	62.	379.	.	1,663.	759.	69.	2,932.			
RECLAMATION	459.	1,702.	.	4,672.	1,063.	311.	8,207.			
SYNGAS	.	.	.	.	.	.	.			
STUDY AREA GENERATION	9,853.	304.	.	13,804.	5,982.	.	30,033.			
SLURRY PIPELINE	.	.	.	.	.	.	.			
TOTAL	10,374.	2,475.	.	20,138.	7,804.	381.	41,172.			
LABOR REQUIREMENT (MAN-YEAR-EQUIVALENT/YEAR)										
MINES	67.	351.	.	1,549.	702.	70.	2,739.			
SYNGAS	.	.	.	.	.	.	.			
STUDY AREA GENERATION	159.	7.	.	117.	51.	.	333.			
TOTAL	226.	357.	.	1,666.	753.	70.	3,072.			
CAPITAL REQUIREMENT (MILLION DOLLARS)										
MINES	.	72.	.	356.	187.	10.	626.			
SYNGAS	.	.	.	.	.	.	.			
STUDY AREA GENERATION	.	.	.	.	.	.	.			
TOTAL	.	72.	.	356.	187.	10.	626.			

29 NOV 76 YELLOWSTONE ENERGY STUDY - 2000 HIGH SCENARIO 111070 1. 1. 1.

ITEM	-1- NORTH DAKOTA LIGNITE	-2- EASTERN MONTANA LIGNITE	-3- MONTANA POWDER R. LIGNITE	-4- MONTANA POWDER R. SUBBIT.	-5- WYOMING POWDER R. LIGNITE	-6- WYOMING POWDER R. SUBBIT.	TOTAL STUDY AREA	-8- COLORADO	-9- SOUTHERN WYOMING	TOTAL PIES REGIONS 7+8
LAND REQUIREMENTS										
STRIP MINING (ACRES/YEAR)	6,061.	692.	2,880.	2,880.	1,436.	80.	14,029.			
SITES (ACRES)										
MINES	4,748.	903.	6,000.	6,000.	6,000.	104.	23,755.			
SYNGAS	5,042.	.	3,002.	.	2,652.	.	10,696.			
STUDY AREA GENERATION	8,873.	50.	.	900.	390.	.	10,214.			
TOTAL	18,663.	953.	9,002.	6,900.	9,042.	104.	44,665.			
AIR POLLUTANT EMISSIONS (TONS/YEAR)										
PARTICULATES	30,655.	79.	6,105.	2,761.	6,585.	.	46,185.			
SULFUR OXIDES	357,363.	946.	67,032.	33,129.	73,541.	.	532,011.			
NITROGEN OXIDES	279,211.	789.	44,745.	27,607.	51,493.	.	403,845.			

18 DEC 76 YELLOWSTONE ENERGY STUDY - 2000 NO CONVERSION SCENARIO 111070 1. 0. 1.

SUMMARY TABLE

RESOURCE REQUIREMENTS IN YELLOWSTONE BASIN STUDY AREA

MINING AREA

ITEM	-1- NORTH DAKOTA LIGNITE	-2- EASTERN MONTANA LIGNITE	-3- MONTANA POWDER R. LIGNITE	-4- MONTANA POWDER R. SUBBIT.	-5- WYOMING POWDER R. LIGNITE	-6- WYOMING POWDER R. SUBBIT.	TOTAL STUDY AREA	-8- COLORADO	-9- SOUTHERN WYOMING	TOTAL PIES REGIONS 7+8
COAL PRODUCTION (MILLION TONS/YEAR)	43.80	22.34	108.86	200.00	200.00	3.47	578.47	90.00	50.00	718.47
BTU CONTENT (MILLION BTU/TON)	13.57	13.40	15.20	17.39	16.45	18.90		20.83	17.24	
COAL CONSUMPTION (MILLION TONS/YEAR)										
STUDY AREA GENERATION	2.97	.12	.00	3.11	1.43	.00	7.64			
SYNGAS	.00	.00	.00	.00	.00	.00	.00			
STUDY AREA GENERATION										
(MEGAWATT CAPACITY)	1,220.	50.	.	900.	390.	.	2,561.			
(GIGAWATT-HOUR/YEAR)	3,849.	158.	.	5,521.	2,393.	.	11,920.			
WATER REQUIREMENT (ACRE-FEET/YEAR)										
MINES	876.	447.	2,177.	4,000.	4,000.	69.	11,569.			
RECLAMATION	6,526.	2,004.	6,118.	11,240.	5,600.	311.	31,800.			
SYNGAS	.	.	.	.	.	.	.			
STUDY AREA GENERATION	9,621.	394.	.	13,804.	5,982.	.	29,801.			
SLURRY PIPELINE	.	.	69,981.	51,490.	32,342.	.	153,813.			
TOTAL	17,024.	2,846.	78,277.	80,533.	47,923.	381.	226,983.			
LABOR REQUIREMENT (MAN-YEAR-EQUIVALENT/YEAR)										
MINES	882.	413.	2,122.	3,920.	3,700.	70.	11,108.			
SYNGAS	.	.	.	.	.	.	.			
STUDY AREA GENERATION	159.	7.	.	117.	51.	.	333.			
TOTAL	1,041.	420.	2,122.	4,037.	3,751.	70.	11,441.			
CAPITAL REQUIREMENT (MILLION DOLLARS)										
MINES	195.	87.	593.	1,016.	1,020.	10.	2,921.			
SYNGAS	.	.	.	.	.	.	.			
STUDY AREA GENERATION	.	.	.	.	.	.	.			
TOTAL	195.	87.	593.	1,016.	1,020.	10.	2,921.			

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18 DEC 76     YELLOWSTONE ENERGY STUDY - 1985 NO CONVERSION SCENARIO                    111070     1.   1.   1.

                                  -1-        -2-        -3-        -4-        -5-        -6-       TOTAL       -8-        -9-       TOTAL
                                 NORTH     EASTERN    MONTANA    MONTANA    WYOMING    WYOMING     STUDY    COLORADO   SOUTHERN     PIES
         ITEM                    DAKOTA    MONTANA   POWDER R.  POWDER R.  POWDER R.  POWDER R.   AREA                WYOMING    REGIONS
                                LIGNITE    LIGNITE    LIGNITE    SUBBIT.    LIGNITE    SUBBIT.                                     7+8

   LAND REQUIREMENTS
     STRIP MINING
       (ACRES/YEAR)                 118.       436.          .     1,197.       273.        80.     2,104.
     SITES
        (ACRES)
        MINES                        92.       569.          .     2,494.     1,139.       104.     4,398.
        SYNGAS                         .          .          .          .          .          .          .
        STUDY AREA GENERATION     1,220.        50.          .       900.       390.          .     2,561.
        TOTAL                     1,313.       619.          .     3,394.     1,529.       104.     6,959.

   AIR POLLUTANT EMISSIONS
   (TONS/YEAR)
        PARTICULATES              1,971.        79.          .     2,761.     1,196.          .     6,007.
        SULFUR OXIDES            23,648.       946.          .    33,129.    14,356.          .    72,079.
        NITROGEN OXIDES          19,706.       789.          .    27,607.    11,963.          .    60,066.
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01 DEC 76 YELLOWSTONE ENERGY STUDY - 2000 MOST PROBABLE SCENARIO - NORTH DAKOTA LIMITATION 111070 1. 0. 1.

SUMMARY TABLE

RESOURCE REQUIREMENTS IN YELLOWSTONE BASIN STUDY AREA

MINING AREA

ITEM	-1- NORTH DAKOTA LIGNITE	-2- EASTERN MONTANA LIGNITE	-3- MONTANA POWDER R. LIGNITE	-4- MONTANA POWDER R. SUBBIT.	-5- WYOMING POWDER R. LIGNITE	-6- WYOMING POWDER R. SUBBIT.	TOTAL STUDY AREA	-8- COLORADO	-9- SOUTHERN WYOMING	TOTAL PIES REGIONS 7+8
COAL PRODUCTION (MILLION TONS/YEAR)	39.43	30.69	39.18	200.00	127.59	3.47	440.56	47.00	32.67	520.23
BTU CONTENT (MILLION BTU/TON)	13.57	13.40	15.20	17.39	16.45	18.90		20.83	17.24	
COAL CONSUMPTION (MILLION TONS/YEAR)										
STUDY AREA GENERATION	28.77	.12	1.31	3.11	1.43	.00	34.75			
SYNGAS	10.30	.00	38.00	.00	26.50	.00	74.80			
STUDY AREA GENERATION										
(MEGAWATT CAPACITY)	9,323.	50.	329.	900.	390.	.	10,993.			
(GIGAWATT-HOUR/YEAR)	41,232.	158.	2,019.	5,521.	2,393.	.	51,322.			
WATER REQUIREMENT (ACRE-FEET/YEAR)										
MINES	789.	618.	784.	4,000.	2,552.	69.	8,811.			
RECLAMATION	5,875.	2,770.	2,202.	11,240.	3,573.	311.	25,971.			
SYNGAS	9,986.	.	40,014.	.	31,588.	.	81,588.			
STUDY AREA GENERATION	103,079.	394.	5,047.	13,804.	5,982.	.	128,306.			
SLURRY PIPELINE	.	.	.	.	.	.	.			
TOTAL	119,729.	3,783.	48,046.	29,044.	43,694.	381.	244,676.			
LABOR REQUIREMENT (MAN-YEAR-EQUIVALENT/YEAR)										
MINES	797.	579.	786.	3,920.	2,360.	70.	8,513.			
SYNGAS	624.	.	2,502.	.	1,974.	.	5,100.			
STUDY AREA-GENERATION	1,212.	7.	43.	117.	51.	.	1,429.			
TOTAL	2,633.	585.	3,330.	4,037.	4,385.	70.	15,042.			
CAPITAL REQUIREMENT (MILLION DOLLARS)										
MINES	155.	112.	219.	1,016.	647.	10.	2,160.			
SYNGAS	998.	.	4,003.	.	3,160.	.	8,161.			
STUDY AREA GENERATION	2,656.	.	108.	.	.	.	2,764.			
TOTAL	3,809.	112.	4,329.	1,016.	3,807.	10.	13,085.			

18 DEC 76 YELLOWSTONE ENERGY STUDY - 2000 NO CONVERSION SCENARIO 111070 1. 1. 1.

ITEM	-1- NORTH DAKOTA LIGNITE	-2- EASTERN MONTANA LIGNITE	-3- MONTANA POWDER R. LIGNITE	-4- MONTANA POWDER R. SUBBIT.	-5- WYOMING POWDER R. LIGNITE	-6- WYOMING POWDER R. SUBBIT.	TOTAL STUDY AREA	-8- COLORADO	-9- SOUTHERN WYOMING	TOTAL PIES REGIONS 7+8
LAND REQUIREMENTS										
STRIP MINING										
(ACRES/YEAR)	1,678.	514.	1,568.	2,880.	1,436.	80.	8,155.			
SITES										
(ACRES)										
MINES	1,314.	670.	3,266.	6,000.	6,000.	104.	17,354.			
SYNGAS	.	.	.	.	.	.	.			
STUDY AREA GENERATION	1,220.	50.	.	900.	390.	.	2,561.			
TOTAL	2,534.	720.	3,266.	6,900.	6,390.	104.	19,915.			
AIR POLLUTANT EMISSIONS										
(TONS/YEAR)										
PARTICULATES	1,924.	79.	.	2,761.	1,196.	.	5,960.			
SULFUR OXIDES	23,091.	946.	.	33,129.	14,356.	.	71,523.			
NITROGEN OXIDES	19,243.	789.	.	27,607.	11,963.	.	59,602.			

02 DEC 76 YELLOWSTONE ENERGY STUDY -2000 HI- 25(MARKET SHARE 111070 1. 0. 1.

SUMMARY TABLE

RESOURCE REQUIREMENTS IN YELLOWSTONE BASIN STUDY AREA

MINING AREA

ITEM	-1- NORTH DAKOTA LIGNITE	-2- EASTERN MONTANA LIGNITE	-3- MONTANA POWDER R. LIGNITE	-4- MONTANA POWDER R. SUBBIT.	-5- WYOMING POWDER R. LIGNITE	-6- WYOMING POWDER R. SUBBIT.	TOTAL STUDY AREA	-8- COLORADO	-9- SOUTHERN WYOMING	TOTAL PIES REGION 7+8
COAL PRODUCTION (MILLION TONS/YEAR)	140.55	3.00	127.89	200.00	200.00	3.47	678.91	150.00	84.00	908.
BTU CONTENT (MILLION BTU/TON)	13.57	13.40	15.20	17.39	16.45	18.90		20.83	17.29	
COAL CONSUMPTION (MILLION TONS/YEAR)										
STUDY AREA GENERATION	27.35	.12	3.20	3.11	1.43	.00	35.21			
SYNGAS	104.00	.00	57.00	.00	44.50	.00	205.50			
STUDY AREA GENERATION										
(MEGAWATT CAPACITY)	7,154.	50.	804.	900.	390.	.	9,299.			
(GIGAWATT-HOUR/YEAR)	40,235.	158.	4,933.	5,521.	2,393.	.	53,239.			
WATER REQUIREMENT (ACRE-FEET/YEAR)										
MINES	2,811.	60.	2,558.	4,000.	4,000.	69.	13,498.			
RECLAMATION	20,942.	269.	7,187.	11,240.	5,600.	311.	45,550.			
SYNGAS	100,528.	.	60,021.	.	53,044.	.	213,893.			
STUDY AREA GENERATION	100,588.	394.	12,331.	13,804.	5,982.	.	133,099.			
SLURRY PIPELINE	.	.	43,696.	14,693.	23,314.	.	81,704.			
TOTAL	225,169.	723.	125,793.	43,737.	91,940.	381.	487,743.			
LABOR REQUIREMENT (MAN-YEAR-EQUIVALENT/YEAR)										
MINES	2,898.	56.	2,497.	3,920.	3,700.	70.	13,141.			
SYNGAS	6,301.	.	3,752.	.	3,315.	.	13,369.			
STUDY AREA GENERATION	930.	7.	105.	117.	51.	.	1,209.			
TOTAL	10,130.	62.	6,354.	4,037.	7,066.	70.	27,719.			
CAPITAL REQUIREMENT (MILLION DOLLARS)										
MINES	659.	.	698.	1,016.	1,020.	10.	3,403.			
SYNGAS	10,079.	.	6,004.	.	5,307.	.	21,390.			
STUDY AREA GENERATION	1,941.	.	263.	.	.	.	2,204.			
TOTAL	12,679.	.	6,965.	1,016.	6,326.	10.	26,997.			

01 DEC 76 YELLOWSTONE ENERGY STUDY - 2000 MOST PROBABLE SCENARIO - NORTH DAKOTA LIMITATION 111070 1. 1. 1.

ITEM	-1- NORTH DAKOTA LIGNITE	-2- EASTERN MONTANA LIGNITE	-3- MONTANA POWDER R. LIGNITE	-4- MONTANA POWDER R. SUBBIT.	-5- WYOMING POWDER R. LIGNITE	-6- WYOMING POWDER R. SUBBIT.	TOTAL STUDY AREA	-8- COLORADO	-9- SOUTHERN WYOMING	TOTAL PIES REGIO 7+8
LAND REQUIREMENTS										
STRIP MINING (ACRES/YEAR)	1,510.	710.	564.	2,880.	916.	80.	6,661.			
SITES (ACRES)										
MINES	1,183.	927.	1,175.	6,000.	3,828.	104.	13,217.			
SYNGAS	499.	.	2,001.	.	1,579.	.	4,080.			
STUDY AREA GENERATION	9,323.	50.	329.	900.	390.	.	10,993.			
TOTAL	11,006.	977.	3,506.	6,900.	5,797.	104.	28,290.			
AIR POLLUTANT EMISSIONS (TONS/YEAR)										
PARTICULATES	21,631.	79.	5,079.	2,761.	4,405.	.	33,956.			
SULFUR OXIDES	258,535.	946.	56,801.	33,129.	49,601.	.	399,012.			
NITROGEN OXIDES	213,605.	789.	39,924.	27,607.	35,503.	.	317,428.			

SUMMARY TABLE

RESOURCE REQUIREMENTS IN YELLOWSTONE BASIN STUDY AREA

MINING AREA

ITEM	-1- NORTH DAKOTA LIGNITE	-2- EASTERN MONTANA LIGNITE	-3- MONTANA POWDER R. LIGNITE	-4- MONTANA POWDER R. SUBBIT.	-5- WYOMING POWDER R. LIGNITE	-6- WYOMING POWDER R. SUBBIT.	TOTAL STUDY AREA	-8- COLORADO	-9- SOUTHERN WYOMING	TOTAL PIES REGIONS 7+8
COAL PRODUCTION (MILLION TONS/YEAR)	39.43	40.13	.00	43.21	46.45	3.47	172.68	20.00	13.21	205.89
BTU CONTENT (MILLION BTU/TON)	13.74	13.40	14.20	17.39	16.45	18.90		20.83	17.24	.
COAL CONSUMPTION (MILLION TONS/YEAR)										
STUDY AREA GENERATION	15.69	.12	.00	3.20	1.43	.00	20.44			
SYNGAS	10.30	.00	.00	.00	.00	.00	10.30			
STUDY AREA GENERATION										
(MEGA-WATT CAPACITY)	6,191.	50.	.	1,353.	390.	.	7,983.			
(GIGA-WATT-HOUR/YEAR)	21,678.	158.	.	5,613.	2,393.	.	29,841.			
WATER REQUIREMENT (ACRE-FEET/YEAR)										
MINES	789.	803.	.	864.	929.	69.	3,454.			
RECLAMATION	5,875.	3,599.	.	2,428.	1,301.	311.	13,514.			
SYNGAS	9,986.	.	.	.	.	.	9,986.			
STUDY AREA GENERATION	54,194.	394.	.	14,033.	5,982.	.	74,603.			
SLURRY PIPELINE	.	.	.	.	.	.	.			
TOTAL	70,843.	4,796.	.	17,325.	8,211.	381.	101,556.			
LABOR REQUIREMENT (MAN-YEAR-EQUIVALENT/YEAR)										
MINES	797.	768.	.	810.	859.	70.	3,305.			
SYNGAS	624.	.	.	.	.	.	624.			
STUDY AREA GENERATION	805.	7.	.	176.	51.	.	1,038.			
TOTAL	2,226.	775.	.	986.	910.	70.	4,967.			
CAPITAL REQUIREMENT (MILLION DOLLARS)										
MINES	155.	157.	.	149.	231.	10.	702.			
SYNGAS	998.	.	.	.	.	.	998.			
STUDY AREA GENERATION	1,632.	.	.	148.	.	.	1,780.			
TOTAL	2,785.	157.	.	297.	231.	10.	3,480.			

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ITEM	-1- NORTH DAKOTA LIGNITE	-2- EASTERN MONTANA LIGNITE	-3- MONTANA POWDER R. LIGNITE	-4- MONTANA POWDER R. SUBBIT.	-5- WYOMING POWDER R. LIGNITE	-6- WYOMING POWDER R. SUBBIT.	TOTAL STUDY AREA	-8- COLORADO	-9- SOUTHERN WYOMING	TOTAL PIES REGIONS 7+8
LAND REQUIREMENTS										
STRIP MINING (ACRES/YEAR)	5,383.	69.	1,842.	2,880.	1,436.	80.	11,689.			
SITES (ACRES)										
MINES	4,216.	90.	3,837.	6,000.	6,000.	104.	20,247.			
SYNGAS	5,042.	.	3,002.	.	2,652.	.	10,696.			
STUDY AREA GENERATION	7,154.	50.	804.	900.	390.	.	9,299.			
TOTAL	16,412.	140.	7,643.	6,900.	9,042.	104.	40,243.			
AIR POLLUTANT EMISSIONS (TONS/YEAR)										
PARTICULATES	30,370.	79.	8,571.	2,761.	6,585.	.	48,366.			
SULFUR OXIDES	353,938.	946.	96,627.	33,129.	73,541.	.	558,182.			
NITROGEN OXIDES	276,357.	789.	69,408.	27,607.	51,493.	.	425,653.			

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SUMMARY TABLE

RESOURCE REQUIREMENTS IN YELLOWSTONE BASIN STUDY AREA

MINING AREA

ITEM	-1- NORTH DAKOTA LIGNITE	-2- EASTERN MONTANA LIGNITE	-3- MONTANA POWDER R. LIGNITE	-4- MONTANA POWDER R. SUBBIT.	-5- WYOMING POWDER R. LIGNITE	-6- WYOMING POWDER R. SUBBIT.	TOTAL STUDY AREA	-8- COLORADO	-9- SOUTHERN WYOMING	TOTAL PIES REGIONS 7+8
COAL PRODUCTION (MILLION TONS/YEAR)	131.76	100.13	37.99	113.70	146.37	3.47	533.42	42.00	20.00	595.42
BTU CONTENT (MILLION BTU/TON)	13.74	13.40	14.20	17.39	16.45	18.90		20.83	17.24	
COAL CONSUMPTION (MILLION TONS/YEAR)										
STUDY AREA GENERATION	28.18	.12	.00	13.70	10.32	.00	52.32			
SYNGAS	83.00	.00	38.00	.00	26.50	.00	147.50			
STUDY AREA GENERATION										
(MEGAWATT CAPACITY)	11,873.	50.	.	4,588.	4,708.	.	21,219.			
(GIGAWATT-HOUR/YEAR)	38,674.	198.	.	25,454.	16,011.	.	80,296.			
WATER REQUIREMENT (ACRE-FEET/YEAR)										
MINES	2,635.	2,003.	760.	2,274.	2,927.	69.	10,668.			
RECLAMATION	19,632.	8,981.	2,135.	6,390.	4,098.	311.	41,548.			
SYNGAS	80,469.	.	40,014.	.	31,588.	.	152,071.			
STUDY AREA GENERATION	96,685.	394.	.	63,635.	40,026.	.	200,741.			
SLURRY PIPELINE	.	.	.	.	.	.	.			
TOTAL	199,421.	11,378.	42,909.	72,299.	78,640.	381.	405,028.			
LABOR REQUIREMENT (MAN-YEAR-EQUIVALENT/YEAR)										
MINES	2,664.	1,998.	764.	2,151.	2,709.	70.	10,356.			
SYNGAS	5,029.	.	2,502.	.	1,974.	.	9,505.			
STUDY AREA GENERATION	1,544.	7.	.	596.	612.	.	2,759.			
TOTAL	9,236.	2,005.	3,265.	2,747.	5,295.	70.	22,619.			
CAPITAL REQUIREMENT (MILLION DOLLARS)										
MINES	606.	445.	213.	524.	744.	10.	2,543.			
SYNGAS	8,044.	.	4,003.	.	3,160.	.	15,207.			
STUDY AREA GENERATION	3,499.	.	.	1,206.	1,419.	.	6,124.			
TOTAL	12,150.	445.	4,215.	1,731.	5,322.	10.	23,873.			

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ITEM	-1- NORTH DAKOTA LIGNITE	-2- EASTERN MONTANA LIGNITE	-3- MONTANA POWDER R. LIGNITE	-4- MONTANA POWDER R. SUBBIT.	-5- WYOMING POWDER R. LIGNITE	-6- WYOMING POWDER R. SUBBIT.	TOTAL STUDY AREA	-8- COLORADO	-9- SOUTHERN WYOMING	TOTAL PIES REGION 7+8
LAND REQUIREMENTS										
STRIP MINING										
(ACRES/YEAR)	1,510.	923.	.	622.	334.	80.	3,468.			
SITES										
(ACRES)										
MINES	1,183.	1,204.	.	1,296.	1,394.	104.	5,180.			
SYNGAS	499.	.	.	.	.	.	499.			
STUDY AREA GENERATION	6,191.	50.	.	1,353.	390.	.	7,983.			
TOTAL	7,873.	1,254.	.	2,649.	1,784.	104.	13,663.			
AIR POLLUTANT EMISSIONS										
(TONS/YEAR)										
PARTICULATES	11,854.	79.	.	2,807.	1,196.	.	15,936.			
SULFUR OXIDES	101,211.	946.	.	33,678.	14,356.	.	190,191.			
NITROGEN OXIDES	115,835.	789.	.	28,065.	11,963.	.	156,652.			

03 AUG 76 YELLOWSTONE ENERGY STUDY - 1985 HIGH SCENARIO - ALTERNATE NETWORK 111070 1. 0. 1.

SUMMARY TABLE

RESOURCE REQUIREMENTS IN YELLOWSTONE BASIN STUDY AREA

MINING AREA

ITEM	-1- NORTH DAKOTA LIGNITE	-2- EASTERN MONTANA LIGNITE	-3- MONTANA POWDER R. LIGNITE	-4- MONTANA POWDER R. SUBBIT.	-5- WYOMING POWDER R. LIGNITE	-6- WYOMING POWDER R. SUBBIT.	TOTAL STUDY AREA	-8- COLORADO	-9- SOUTHERN WYOMING	TOTAL PIES REGIONS 7+8
COAL PRODUCTION (MILLION TONS/YEAR)	59.07	44.50	3.19	100.00	89.46	3.47	299.69	27.00	19.67	346.
BTU CONTENT (MILLION BTU/TON)	13.74	13.40	14.20	17.39	16.45	18.90		20.83	17.24	
COAL CONSUMPTION (MILLION TONS/YEAR)										
STUDY AREA GENERATION	18.92	.12	3.20	3.11	1.43	.00	26.78			
SYNGAS	10.30	.00	.00	.00	.00	.00	10.30			
STUDY AREA GENERATION										
(MEGAWATT CAPACITY)	7,151.	50.	804.	900.	390.	.	9,296.			
(GIGAWATT*HOUR/YEAR)	26,383.	158.	4,933.	5,521.	2,393.	.	39,387.			
WATER REQUIREMENT (ACRE-FEET/YEAR)										
MINES	1,181.	890.	64.	2,000.	1,789.	69.	5,994.			
RECLAMATION	8,801.	3,992.	180.	5,620.	2,505.	311.	21,408.			
SYNGAS	9,986.	.	.	.	.	.	9,986.			
STUDY AREA GENERATION	65,957.	394.	12,332.	13,804.	5,982.	.	98,468.			
SLURRY PIPELINE	.	.	.	45,453.	26,641.	.	72,094.			
TOTAL	85,925.	5,276.	12,576.	66,877.	36,917.	381.	207,951.			
LABOR REQUIREMENT (MANYEAR-EQUIVALENT/YEAR)										
MINES	1,210.	858.	59.	1,870.	1,655.	70.	5,722.			
SYNGAS	624.	.	.	.	.	.	624.			
STUDY AREA GENERATION	930.	7.	105.	117.	51.	.	1,209.			
TOTAL	2,764.	865.	164.	1,987.	1,706.	70.	7,555.			
CAPITAL REQUIREMENT (MILLION DOLLARS)										
MINES	258.	178.	17.	446.	450.	10.	1,359.			
SYNGAS	998.	.	.	.	.	.	998.			
STUDY AREA GENERATION	1,947.	.	263.	.	.	.	2,210.			
TOTAL	3,203.	178.	280.	446.	450.	10.	4,567.			

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02 AUG 76   YELLOWSTONE ENERGY STUDY -  2000 MOST PROBABLE SCENARIO - ALTERNATE NETWORK       111070     1.   1.   1.

                                 -1-        -2-        -3-        -4-        -5-        -6-       TOTAL       -8-        -9-       TOTAL
         ITEM                   NORTH     EASTERN    MONTANA    MONTANA    WYOMING    WYOMING    STUDY    COLORADO  SOUTHERN    PIES
                                DAKOTA    MONTANA   POWDER R.  POWDER R.  POWDER R.  POWDER R.   AREA                WYOMING   REGIONS
                               LIGNITE    LIGNITE    LIGNITE    SUBBIT.    LIGNITE    SUBBIT.                                   7+8
    LAND REQUIREMENTS
      STRIP MINING
        (ACRES/YEAR)              5,046.     2,303.       547.     1,637.     1,051.        80.    10,664.
      SITES
        (ACRES)
        MINES                     3,953.     3,004.     1,140.     3,411.     4,391.       104.    16,002.
        SYNGAS                    4,024.          .     2,001.          .     1,579.          .     7,605.
        STUDY AREA GENERATION    11,873.        50.          .     4,588.     4,708.          .    21,219.
        TOTAL                    19,850.     3,054.     3,141.     7,999.    10,678.       104.    44,827.

    AIR POLLUTANT EMISSIONS
    (TONS/YEAR)
        PARTICULATES             27,519.        79.     4,070.    12,727.    11,214.          .    55,609.
        SULFUR OXIDES           321,851.       946.    44,688.   152,724.   131,308.          .   651,518.
        NITROGEN OXIDES         253,372.       789.    29,830.   127,270.  -103,593.          .   514,853.
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03 AUG 76 YELLOWSTONE ENERGY STUDY - 2000 HIGH SCENARIO - ALTERNATE NETWORK 111070 1. 0. 1.

SUMMARY TABLE

RESOURCE REQUIREMENTS IN YELLOWSTONE BASIN STUDY AREA

	MINING AREA									
ITEM	-1- NORTH DAKOTA LIGNITE	-2- EASTERN MONTANA LIGNITE	-3- MONTANA POWDER R. LIGNITE	-4- MONTANA POWDER R. SUBBIT.	-5- WYOMING POWDER R. LIGNITE	-6- WYOMING POWDER R. SUBBIT.	TOTAL STUDY AREA	-8- COLORADO	-9- SOUTHERN WYOMING	TOTAL PIES REGIONS 7+8
COAL PRODUCTION (MILLION TONS/YEAR)	152,75	100.23	151.56	200.00	200.00	3.47	808.01	90.00	46.87	944.88
BTU CONTENT (MILLION BTU/TON)	13.74	13.40	14.20	17.39	16.45	18.90		20.83	17.28	
COAL CONSUMPTION (MILLION TONS/YEAR)										
STUDY AREA GENERATION	22.94	.22	3.20	3.11	1.43	.00	30.90			
SYNGAS	104.00	.00	57.00	.00	44.50	.00	205.50			
STUDY AREA GENERATION										
(MEGAWATT CAPACITY)	7,153.	50.	804.	900.	390.	.	9,298.			
(GIGAWATT*HOUR/YEAR)	32,987.	307.	4,933.	5,521.	2,393.	.	46,140.			
WATER REQUIREMENT (ACRE-FEET/YEAR)										
MINES	3,055.	2,005.	3,031.	4,000.	4,000.	69.	16,160.			
RECLAMATION	22,760.	8,990.	8,518.	11,240.	5,600.	311.	57,420.			
SYNGAS	100,828.	.	60,021.	.	53,044.	.	213,893.			
STUDY AREA GENERATION	82,467.	767.	12,331.	13,804.	5,982.	.	115,351.			
SLURRY PIPELINE	8,527.	.	48,479.	75,953.	23,673.	.	156,631.			
TOTAL	217,638.	11,762.	132,380.	104,996.	92,299.	381.	559,455.			
LABOR REQUIREMENT (MAN*YEAR-EQUIVALENT/YEAR)										
MINES	3,163.	2,000.	2,982.	3,916.	3,700.	70.	15,831.			
SYNGAS	6,301.	.	3,752.	.	3,315.	.	13,369.			
STUDY AREA GENERATION	930.	7.	105.	117.	51.	.	1,209.			
TOTAL	10,394.	2,006.	6,839.	4,033.	7,066.	70.	30,409.			
CAPITAL REQUIREMENT (MILLION DOLLARS)										
MINES	726.	445.	833.	1,008.	1,020.	10.	4,041.			
SYNGAS	10,079.	.	6,004.	.	5,307.	.	21,390.			
STUDY AREA GENERATION	1,944.	.	263.	.	.	.	2,207.			
TOTAL	12,749.	445.	7,100.	1,008.	6,326.	10.	27,639.			

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ITEM	-1- NORTH DAKOTA LIGNITE	-2- EASTERN MONTANA LIGNITE	-3- MONTANA POWDER R. LIGNITE	-4- MONTANA POWDER R. SUBBIT.	-5- WYOMING POWDER R. LIGNITE	-6- WYOMING POWDER R. SUBBIT.	TOTAL STUDY AREA	-8- COLORADO	-9- SOUTHERN WYOMING	TOTA PIES REGIO 7+8
LAND REQUIREMENTS										
STRIP MINING										
(ACRES/YEAR)	2,262.	1,023.	46.	1,440.	642.	80.	5,494.			
SITES										
(ACRES)										
MINES	1,772.	1,335.	96.	3,000.	2,684.	104.	8,991.			
SYNGAS	499.	.	.	.	.	.	499.			
STUDY AREA GENERATION	7,151.	50.	804.	900.	390.	.	9,296.			
TOTAL	9,423.	1,385.	900.	3,900.	3,074.	104.	18,786.			
AIR POLLUTANT EMISSIONS										
(TONS/YEAR)										
PARTICULATES	14,207.	79.	2,466.	2,761.	1,196.	.	20,709.			
SULFUR OXIDES	169,441.	946.	29,597.	33,129.	14,356.	.	247,469.			
NITROGEN OXIDES	139,359.	789.	24,664.	27,607.	11,963.	.	204,383.			

03 AUG 76 YELLOWSTONE ENERGY STUDY - 2000 HIGH SCENARIO - ALTERNATE NETWORK 111078 1. 1. 1.

ITEM	-1- NORTH DAKOTA LIGNITE	-2- EASTERN MONTANA LIGNITE	-3- MONTANA POWDER R. LIGNITE	-4- MONTANA POWDER R. SUBBIT.	-5- WYOMING POWDER R. LIGNITE	-6- WYOMING POWDER R. SUBBIT.	TOTAL STUDY AREA	-8- COLORADO	-9- SOUTHERN WYOMING	TOTAL PIES REGION 7+8
LAND REQUIREMENTS										
STRIP MINING (ACRES/YEAR)	5,851.	2,305.	2,182.	2,880.	1,436.	80.	14,734.			
SITES (ACRES)										
MINES	4,583.	3,007.	4,547.	6,000.	6,000.	104.	24,240.			
SYNGAS	5,042.	.	3,002.	.	2,652.	.	10,696.			
STUDY AREA GENERATION	7,153.	50.	804.	900.	390.	.	9,298.			
TOTAL	16,778.	3,057.	8,353.	6,900.	9,042.	104.	44,235.			
AIR POLLUTANT EMISSIONS (TONS/YEAR)										
PARTICULATES	26,746.	153.	8,571.	2,761.	6,585.	.	44,816.			
SULFUR OXIDES	310,450.	1,840.	96,627.	33,129.	73,541.	.	515,587.			
NITROGEN OXIDES	240,116.	1,534.	69,408.	27,607.	51,493.	.	390,157.			